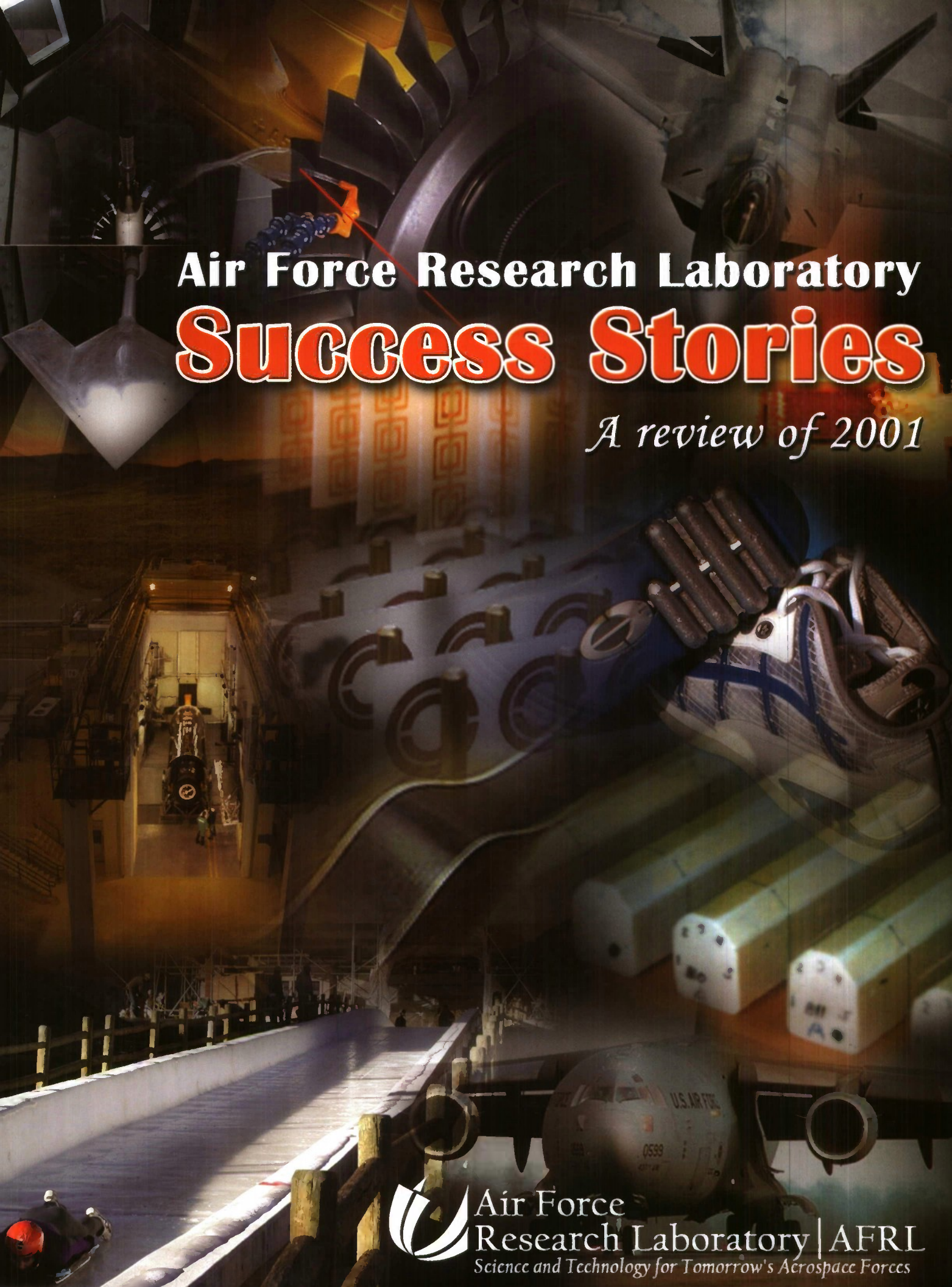

Air Force Research Laboratory

Success Stories

A review of 2001

Air Force Research Laboratory | AFRL

Science and Technology for Tomorrow's Aerospace Forces

To receive more information about any of the success stories in this book, on the CD-ROM or other technical activities in Air Force Research Laboratory, contact the Technology Transfer Branch, AFRL/XPTT, (800) 203-6451.

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AFRL Success Story Program

Helping to maintain the Air Force's strong S&T foundation one success at a time.

The Air Force, established upon the foundation of science and technology (S&T) more than 50 years ago, continues to lead the way into the 21st Century. Senior Air Force leaders recognize the Air Force Research Laboratory's (AFRL's) impact on the Air Force's future and share our belief that S&T is as important as any other part of our aerospace force.

The imagination of the world's most inquiring minds–in government, industry, and academia–provides the best equipment, weapon systems, and ideas driving our organization. These Success Stories showcase some of the work accomplished within AFRL to turn science fiction into science fact and reality, to ensure the Air Force foundation stays strong and continues development, one composite brick at at time.

You'll find in these pages some of our most noteworthy successes for 2001. These stories are just the "tip of the iceberg" of AFRL technologies currently being worked. The accompanying CD-ROM provides the same information as the book in a "shirt pocket" transportable format.

AFRL, headquartered at Wright-Patterson AFB, Ohio, is the Air Force's largest employer of scientists and engineers – about 3,000, of which more than 750 have doctorate degrees in science and engineering disciplines. These highly skilled and motivated personnel are critical in leading our government-industry-university team and in making technology breakthroughs. Their in-house research efforts are pushing known boundaries to new heights in most of the scientific disciplines.

If you want to know more about a Success Story, please contact our technology clearinghouse, TECH CONNECT, at (800) 203-6451 and they will direct you to the appropriate laboratory expert. Also take a moment to check out our home page at http://www.afrl.af.mil.

PAUL D. NIELSEN
Major General, USAF
Commander

Introduction

The Air Force Science and Technology Success Stories herein often represent the combined effort of several scientists and engineers working as a team. The basic and applied research, plus the follow-on technology development described, are essential to the continued success of the Air Force mission.

Success Stories were selected from one or more of the following categories:

Support to the Warfighter

Technology that has potential for or has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations.

Emerging Technologies

Major innovative technological advancements that offer significant potential for existing and future Air Force systems.

Technology Transfer

Technology that has transferred from the laboratory to the private sector, to include industry, academia, and state and local governments.

Awards/Recognition

Awards or recognition by the scientific community at large, concerning technology advancements in the areas of technology transition, technology transfer, or technical achievement.

Support to the Warfighter

State-of-the-Art Visual Display System Developed for Simulation-Based Research and Development

Payoff The Infinity Cube™, a state-of-the-art, color, wide field-of-view visual display system, provides a continuous vertical field-of-view that allows a real world feel, giving out-the-window objects correct size, altitude, and visual cues. Its air-to-ground orientation complements other resources supporting the flying simulations that are the core components of simulation-based research and development.

Accomplishment The Air Vehicles Directorate, Control Simulation and Assessment Branch, recently completed the installation of the one-of-a-kind Infinity Cube. The cube's wide field-of-view provides a visual display system for flight simulation, research, and development. The Infinity Cube's display system surrounds the "pilot" with four Pancake Window™ displays to the front, top, left, and right.

The directorate will use the Infinity Cube to support research for the Joint Strike Fighter and unmanned aerial vehicles. However, the cube has potential to support broader-based research including weapon systems analysis, flying qualities, and networked "war gaming" activities. The Infinity Cube is a unique research tool that the directorate and other organizations will use to support mission simulation for years to come.

Background Electro Visual Engineering (EVE) developed the Infinity Cube as a prototype display system for use as a training device. The Control Simulation and Assessment Branch perceived the potential for simulation-based research and development and arranged to acquire the system. They contracted with EVE to upgrade the system to better suit directorate requirements. EVE increased the cube's image generator and projector resolutions, as well as doubled the channel brightness.

F-16 Test Aircraft Completes Long Distinguished Career

Payoff F-16 tail number 75-0750 flew its first mission in April 1978 and participated in 10 flight test programs since that time. For the past two decades, the aircraft was the technology demonstrator for the Air Vehicles Directorate's Advanced Fighter Technology Integration (AFTI) program. The aircraft helped directorate engineers transition digital flight controls, a night vision system (night vision goggles and compatible cockpit lighting), improved takeoff and landing gear control, and a voice annunciation system.

Accomplishment Aircraft 750 flew its final flight in January 2001 from Ft. Worth, Texas to Wright-Patterson Air Force Base in Dayton, Ohio, for induction into the Air Force Museum. The aircraft, having flown more than 756 flights, accumulated 1446 flight hours under 23-plus test pilots from Lockheed Martin, the US Air Force, the National Aeronautical and Space Administration, the US Marine Corps, the Swedish Air Force, and the Department of Defense Joint Strike Fighter program.

Background The AFTI/F-16 was an excellent test platform due to its modern systems, relative ease of incorporating advanced technologies, and low cost of operation and maintenance. Lockheed Martin originally built aircraft 750 as an F-16A, the sixth "A" model and seventh of eight aircraft in the F-16 Full-Scale Development program. The aircraft's last mission was the very successful Joint Strike Fighter Integrated Subsystems Technology demonstration in Fort Worth during October-November 2000.

The manufacturer modified the AFTI/F-16 with an all-electric flight control system with electrohydrostatic actuators and a 270-volt direct current switched reluctance electric power system. The AFTI/F-16 was the first aircraft to fly with an all-electric flight control system. These technologies reduce weight, improve reliability and maintainability, increase survivability, and trim costs compared to traditional hydraulic actuator systems.

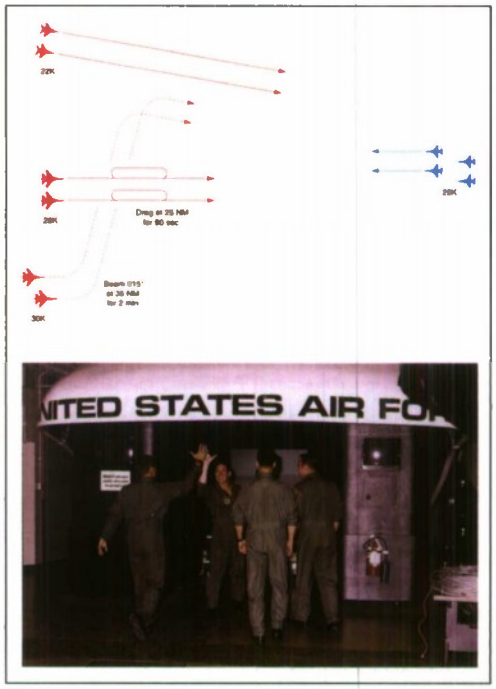
Other AFTI/F-16 technologies transitioning into F-16 production include multifunction displays, dual multiplex bus avionics architecture, wide-angle heads-up display, up-front controls, single-switch mission reconfiguration, dorsal avionics compartment, digital data link, digital terrain system, automatic terrain following, and system-wide integrity management. Prospective items for the F-16 in the near term include helmet-mounted cueing of weapons and sensors, digital color map display, internalized forward looking infrared (FLIR) targeting system, and in-flight route planning.

Advanced technologies demonstrated with promise for the next generation of fighters or for future incorporation on current fighters include voice interaction, auto ground collision avoidance, head-steered FLIR imaging, covert radar altimeter, electric flight control actuation, and cooperative engagement capability (separated target sensor and shooter).

Distributed Mission Training Effectiveness

Payoff The Air Force Distributed Mission Training (DMT) program provides pilots and other warfighters with ground-based training for complex, multi-player combat operations using a network of flight simulators and other systems. This shared training environment, comprised of live, virtual, and constructive simulations, trains warfighters individually or collectively at all levels of war. DMT allows multiple players at multiple sites to engage in instructionally valid training scenarios focusing on individual, team, and intra-team competencies development, as well as refresher training within a realistic combat-oriented environment.

Accomplishment The Human Effectiveness Directorate, Warfighter Training Research Division's Training Systems Technology Team is providing DMT system data to the Air Combat Command (ACC) for aircrew training. This data identifies the tasks and missions best suited for DMT, defines system capabilities required for effective distributed training, and creates a strategy for developing future training programs using DMT for fighter pilots and air weapons controllers. Research using DMT for Flight Leader Upgrade, Instructor Pilot Upgrade, and Fighter Weapons Instructor course training programs demonstrates the return-on-investment available through the effective integration of learning objectives-based DMT syllabi with existing operational academic and live-flight aircraft training.



The directorate, supported by the ACC DMT office, an instructor pilot, and Airborne Warning and Control System (AWACS) controllers, conducted training exercises during 1999-2000 for mission-qualified F-16 pilots. DMT, complemented with aircraft training, enhances warfighter proficiency and reduces the need for repeated training flights at home units. The Fighter Weapons School syllabus served as the initial test and validation for new F-16 weapons employment standards implemented in the school. Directorate personnel at the Mesa test bed evaluated and adjusted the standards more rapidly than using live-flight exclusively.

Background Structured interviews with F-16 instructor pilots and unit commanders indicate that many mission-qualified pilots lack recent experience in four-ship tactics. Reasons include high cost, scheduling difficulties, constrained airspace, very limited availability, and interactions with AWACS controllers. The directorate's Training Systems Technology Team developed and tested DMT training syllabi and measurement methods that augment live-flight aircraft training with high-fidelity, multi-player simulation.

The training research syllabi involve the four-ship, F-16 DMT test bed, located in Mesa, Arizona, integrated with the AWACS simulation facility, located at the directorate's facility at Brooks AFB, Texas. In addition, the syllabi include the constructive integrated air defense system, developed and operated by the Air Force Information Warfare Center at Kelly AFB, Texas.

DMT allows participation from each weapon system and mission area using almost any type of networkable training device. Additionally, computer-generated or constructive DMT provides realistic and reactive threats for developing and evaluating tactics.

Logistician's Contingency Assessment Tools (LOGCAT)

Payoff The Logistician's Contingency Assessment Tools (LOGCAT) suite consists of automated decision support tools for crisis action planning across all levels of command in logistics command and control. These tools support the Air Force Core Competencies of Agile Combat Support and Rapid Global Mobility. They also provide proactive identification of logistics-related mission critical limiting factors through reduced response planning time and execution cycle, deployment footprint, man-hours, and time to deploy at the wing level.

Accomplishment The Human Effectiveness Directorate is providing LOGCAT technologies to aid today's and tomorrow's deployment and beddown planners at all levels of the Air Force (AF). LOGCAT programs have the potential to revolutionize the entire Agile Combat Support planning and execution process.

The Aerospace Expeditionary Force (AEF) Battlelab Integrated Planning and Execution Capability Initiative field tested LOGCAT. They identified these tools as critical AEF enablers to the Air Force Requirements Oversight Council and recommended them for AF implementation.

Several high visibility joint and service-unique wargames/ experiments, such as Global Engagement '98, '99 and Expeditionary Forces Experiment '98, '99, tested LOGCAT as primary logistics inputs. The tools were so successful, the AEF selected them as the Agile Combat Support infrastructure and baseline for Joint Expeditionary Forces Experiment '00 and beyond.

Background The LOGCAT program began in 1995 as an integrated suite of logistics command and control applications developed by Air Staff planners, local contractors, and Major Command functional representatives. Using a combination of commercial off-the-shelf and government proprietary products in its design, the LOGCAT team developed several proof-of-concept software programs.

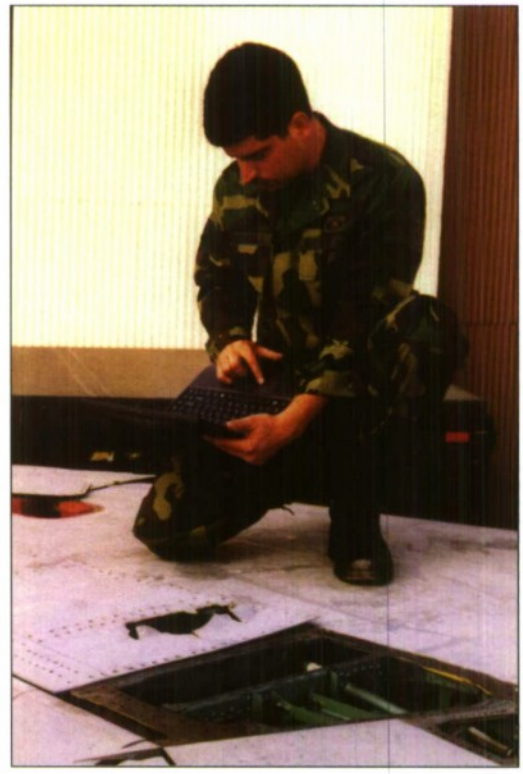
The team designed these tools to operate with existing legacy systems in the Secret Internet Protocol Routing Network environment. The LOGCAT team transitioned three components of the LOGCAT suite (Survey Tool for Employment Planning, Beddown Capability Assessment Tool, and the Employment Knowledge Base) to the Air Staff sponsor and Standard Systems Group at Gunter AFB, Alabama for full operational production and worldwide implementation.

A fourth component of LOGCAT, the Logistics Analysis to Improve Deployability (LOG-AID), shows promise for improving the base-level deployment process. The Air Staff plans to incorporate LOG-AID into AF deployment instructions and policy.

Aircraft Battle Damage Assessment and Repair Program

Payoff The Human Effectiveness Directorate's Aircraft Battle Damage Assessment and Repair (ABDAR) program increases the number of aircraft available for duty by decreasing the time to diagnose damaged aircraft. Over a seven-day air conflict, simulations show ABDAR capabilities can increase the number of sorties available over standard aircraft battle damage repair (ABDR) up to 10%. In a prolonged engagement, the advantages are even greater. In peacetime, ABDAR is an effective ABDR training tool to assess fire- or crash-damaged aircraft, or augment the diagnostic tools available in programmed depot maintenance.

Accomplishment When combined with highly versatile interactive electronic technical manual (IETM) aircraft technical data, the ABDAR assessment logic decreased assessment time 72% over a standard paper-based assessment, while at the same time increasing accuracy by 96%. Using less advanced interactive portable document format (IPDF) aircraft data, ABDAR improved time by 41% and accuracy by 80% over a paper-based assessment. ABDAR also shows that F-15 flightline mechanics can perform assessments almost as well as system specialists when using this system.



Background Specially trained Air Force Materiel Command Combat Logistics Support Squadrons perform ABDR to restore maximum mission capability to combat-damaged aircraft in minimum time. The first step in restoring capability to an aircraft is to assess the extent of damage to the aircraft, which frequently takes longer than the repair process.

The directorate's ABDAR program researches methods to apply advanced assessment logic in conjunction with electronic technical information to improve aircraft damage assessment. The program began with user interviews to identify and define requirements. The directorate then designed and developed an ABDAR demonstration system based on the requirement study.

The demonstration system's portable maintenance aid provides all the information the user requires including assessment and repair logic, technical orders, part information, wiring schematics, and troubleshooting data. Directorate engineers developed technical data using both the IPDF and IETM format. A graphical user interface allows users to easily access and comprehend ABDAR information. A directorate-conducted field test evaluated the effectiveness of IPDF- and IETM-based data, compared to the current paper-based data.

"Training for Dynamic Aerospace Control" Demonstration

Payoff The Human Effectiveness Directorate's Warfighter Training Research Division presented engineering, training, and behavioral solutions for the conduct of asymmetric coalition force operations training at the Air Force Technology Exposition 2000. The Division's "Training for Dynamic Aerospace Control" demonstrated the real-time training potential of ground-based, high fidelity training environments for command and control readiness training in a multi-site, networked environment.

Accomplishment Using a unique, laboratory-developed solution, directorate engineers connected the show site (Marriott Wardman, Washington, D.C.) to the directorate's Distributed Mission Training (DMT) test bed in Mesa, Arizona, over a one megabit-per-second Internet connection using encryption devices at both ends. The local area network in the Mesa test bed consisted of three additional F-16C Multi Task Trainers (MTTs) and an A-10 Unit Training Device. The engineers connected the DMT test bed with a primary rate integrated services digital network line (equivalent to a T-1, 1.5 megabit-per-second data line) to two Royal Air Force Tornado simulators, one virtual and one constructive, provided by Thomson Training and Simulation of Crawley, United Kingdom.

Other networked elements included an E-8 Joint Stars virtual simulation, a virtual Airborne Warning and Control System, E-3B Weapons Director simulator, a virtual Space Maneuvering Vehicle concept simulator, one Predator uninhabited air vehicle (UAV) MTT, joint semi-automated forces for multiple friendly (blue) and enemy (red) intelligent agent constructive forces, the Automated Threat Engagement System for multiple blue and red forces, and a Mission Control Station. During the real-time demonstration, all virtual players could see, fly with, and talk to each other.

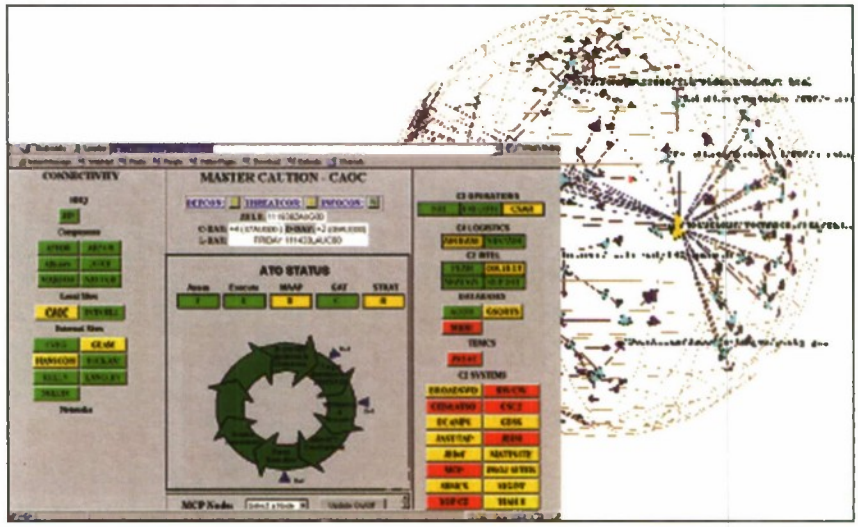
The demonstration focused on training to accomplish the six stages of the operational chain: find, fix, track, target, engage, and assess. The directorate designed the training scenario to emulate a combined air operation event. Mission elements included suppression of enemy air defenses, offensive counter air, close tactical control for air-to-air engagements, air-to-ground strike missions, real-time reconnaissance with Joint Stars and the UAV, use of overhead space assets, and real-time re-targeting by the Combined Air Operations Center of F-16s and A-10s against Scuds and moving tank columns. The performance of the networks, the quality of the voice transmissions, and the overall validity of the training concepts were unqualified successes.

Background The Warfighter Training Research Division conducted the demonstration using technology assets and simulation interoperability communication protocols currently in existence for distributed air and ground simulations. The demonstration also supported virtual representations of major components of the command and control infrastructure in both the United States and the United Kingdom. The Air Force Association invited the Warfighter Training Research Division to the 2000 exposition because of their outstanding performance at the 1999 Aerospace Technology Exposition and Annual Convention.

Configurable Aerospace Command Center Master Caution Panel Supports Warfighter

Payoff Information Directorate engineers demonstrated the Configurable Aerospace Command Center (CACC) Master Caution Panel (MCP) during Joint Expeditionary Force Experiment (JEFX) 2000. JEFX 2000 is a major exercise used to expedite building the expeditionary Air Force for the 21st century. JEFX uses live fly and simulations to evaluate new operational concepts and emerging technologies. This exercise features a number of experiments focusing on agile combat support and time-critical targeting. The MCP met or exceeded all criteria during the Air Force Experimentation Office's evaluation.

Accomplishment Directorate engineers delivered and installed the new Java-based version of MCP at multiple sites. The demonstration included an automatic display of the health status of the JEFX networks using BBN Technologies' information management system and Hewlett-Packard OpenView, the network management system used by the JEFX Networks Operation Center.



Background The directorate's Systems Concepts and Applications Branch, working closely with the Aerospace Command and Control Intelligence Surveillance and Reconnaissance Center (AC2ISRC), developed user interface modifications according to the Joint Battlespace Infosphere Management Process initiative. The Human Effectiveness Directorate's Crew System Interface Division performed task analysis of warfighter needs for the MCP. The operational experience and direction of the JEFX participants assisted the developers in building upon the delivered version of MCP, yielding a more robust capability to the warfighter.

Directorate engineers installed the new Java-based version at Hurlburt Field, Florida; Nellis AFB, Nevada; and Langley AFB, Virginia. Electronic Systems Command and the AC2ISRC upgraded the MCP program to a category I advanced technology demonstration.

AFRL Successfully Demonstrates Theater Ballistic Missile Reasoner

Payoff Alphatech and the Information Directorate's Fusion and Intelligent Information Systems Branches demonstrated Alphatech's Theater Ballistic Missile (TBM) Reasoner at the Joint Expeditionary Force Experiment (JEFX) 2000. JEFX 2000, a large- scale experiment preparing the Air Force for the challenges of the 21st century expeditionary operations, features a number of smaller experiments focusing on agile combat support and time-critical targeting. The TBM Reasoner provides the capability to support the increased operational tempo of intelligence, surveillance, and reconnaissance (ISR) collection and attack operations against TBM time-critical targets through the integration of fusion and knowledge-based technologies.

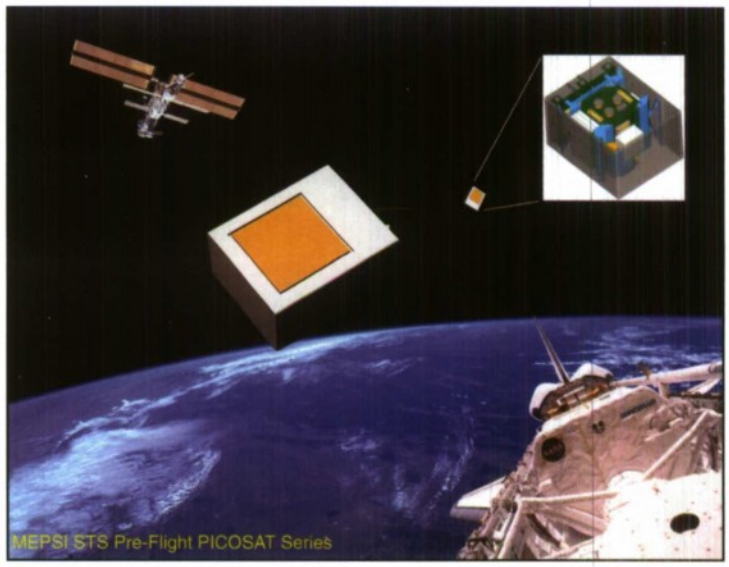
Accomplishment The TBM Reasoner helps identify TBM objects from sensor data in near real time and generates named areas of interest to focus ISR planning/collection and updates of intelligence preparation of the battlefield. The TBM Reasoner also uses movement analysis/TBM identification to discriminate against postulated enemy courses of action.

Background Current manual methods for finding TBMs are not successful. The state of practice for the identification of TBM vehicles requires analysts to sift through large amounts of data, seeking patterns of activity consistent with expected TBM vehicle behavior. Analysts do not examine as much as 80% of the data due to information overload. The TBM Reasoner uses knowledge base and other artificial intelligence techniques to assist the analyst in the near real-time identification of TBM vehicles. The general consensus of potential Air Force users of the TBM Reasoner was that the technology is extremely valuable and needed. Other potential application areas for the TBM Reasoner include locating engineering bridging units and drug smuggling watercraft.

Information Directorate Program Passes NASA Review for Space Shuttle Flight

Payoff The National Aeronautics and Space Administration (NASA) approved an Information Directorate miniature self-inspection system payload for inclusion on the Space Shuttle. This self-inspection system enhances satellite command and control operations by providing active onboard imaging capability to assess spacecraft damages from man-made or environmental threats, monitors launch operations, and augments servicing operations.

Accomplishment The directorate's miniature self-inspection system provides decision makers with a rapid feedback capability for detection and response to spacecraft anomalies for maintaining ultimate satellite longevity. Directorate engineers can develop the miniature self-inspection system for a particular space system or for carrying aboard virtually any host vehicle.



Operationally, the directorate's self-inspection system demonstrates the capability to store a miniature self-inspection system that can be released to conduct surveillance of its host vehicle for independent situational awareness. Once released from the host, the directorate's miniature self-inspection system assumes full autonomous control by using inertial sensors, microthrusters, reaction wheels, and high-level "smart" processing.

The directorate's miniature self-inspection system can either downlink image data in real time to the ground station or store it for downlink for future passes over the ground station. The directorate developed two concepts: "Space Onboard Servicer and Space Onboard Protector." The directorate's miniature self-inspection system provides the basis for implementing required proof-of-concept for each.

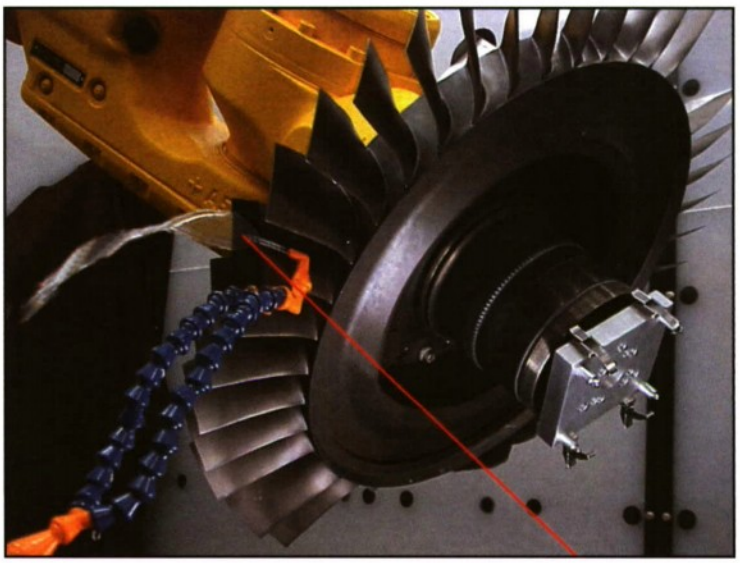
Background The directorate's Advanced Computing Architecture Branch met with NASA for a combined safety review of this miniature self-inspection system payload. The NASA safety panel meticulously reviewed the directorate's miniature self-inspection system hardware for any concerns or hazards that could impact mission and flight crew safety.

Representatives from the Aerospace Corporation (the program's hardware integrator), the directorate, and NASA gathered and met all safety board requirements. The uniqueness of the directorate's miniature self-inspection system payload and the thorough design of the hardware allowed NASA to combine the first three safety reviews into one. NASA stated that this self-inspection system is the smallest payload ever deployed by the Space Shuttle program. The miniature self-inspection system's small size and mass (less than 1 kg) allow it to fly in previously unusable cargo bay locations.

Laser Shock Peening - the Right Technology at the Right Time

Payoff The Materials and Manufacturing Directorate is developing a laser shock peening (LSP) process that toughens aircraft turbine engine blades greater than five times the normal fatigue strength. Tougher engine blades result in greater resistance to foreign object damage (FOD) and less risk to aircraft and pilots. This technology provides a cost avoidance of over $100 million above and beyond the savings in preflight inspections and aircraft losses.

Accomplishment Application of this technology avoided over $59 million in reduced blade replacement costs, reduced secondary damage engine repair costs, and avoided cost from airfoil failures. Avoiding 42 catastrophic failures over the remaining life of the B-1B/F101 program may result in another $40 million cost avoidance savings. This, added to the money saved by avoiding the redesign of the F119, is a cost avoidance of more than $100 million. Directorate engineers project a similar impact on the F110. Potential savings could easily approach $1 billion when calculating this impact over all the engines in the Air Force fleet.



Background Beginning in 1991, the B-1's F101 engine began experiencing failures of titanium turbine blades due to FOD caused by ice and hard objects ingested into the engine. Chunks of blades that broke loose, in some cases, did irreparable damage on the rest of the engine. General Electric Aircraft Engines (GEAE), under license from Battelle Memorial Institute, investigated the little known technology, called LSP, as a potential solution to increase the durability of titanium fan blades and decrease the sensitivity to FOD.

LSP uses a strong laser pulse to impart high compressive residual stresses into the leading-edge surface of metal blades. The laser pulse ignites a blast or shock wave from the specially coated surface of the blade. The expansion of the blast wave then creates a travelling stress wave into the blade, thereby compressing the material surface. The resulting surface compressive residual stress significantly improves the high-cycle fatigue properties of the blade and greatly increases resistance to blade failure caused by FOD.

In 1995, the Air Force decided to move ahead with the production development of LSP technology, bringing this technology out of the lab and into the production environment. By 1997, GEAE proved the beneficial effects of LSP and began production of titanium blades. Current Air Force efforts with LSP Technologies, supplier of commercial laser equipment and services, focused on maturing LSP manufacturing capabilities and implementing commercially affordable production manufacturing cells for application to turbine engine blades and components. While this new technology's production costs are relatively high, the benefits far outweigh inspection and replacement costs.

Ceramic Materials Technology Streamlines Aircraft Component Inspection Process

Payoff Research shows a new ceramic calibration block (MACOR™), incorporating thin-gage wire, is an acceptable substitute for the current electro-discharge machined (EDM) blocks used for the standard retirement for cause (RFC) calibration. Using the MACOR block concept requires no change in the scanning pattern, system software, or gain calibration, and saves time by reducing the number of index scans required. Aside from reductions in calibration times, the benefits include a 50% reduction in block cost and significant reductions in the property control and utilization logistics associated with the EDM notch calibration blocks. Air Force aircraft using turbine engines will benefit greatly from these improvements.

Accomplishment Scientists and engineers at the Materials and Manufacturing Directorate, working with the University of Dayton Research Institute identified an efficient, cost-effective means for improving one of the inspection processes for turbine engine components and other critical aircraft parts. The researchers identified and developed a ceramic calibration block concept to replace all EDM blocks currently used to set the gain and phase angle for RFC-based eddy current inspections. Directorate engineers expect the new block, made of a machinable ceramic material called MACOR, to save several hundred dollars per block and simplify the inspection process, as well as ensure the reliability of component part life-expectancy testing.

Background In the current budgetary environment, the Air Force often uses fielded equipment beyond its design life. To avoid the large cost of replacing critical rotating parts, an RFC program may prove to be a cost-effective, safe alternative. Studies indicate, for example, that about 80% of the parts replaced at low-cycle, fatigue-calculated, "safe life" limits have an order of magnitude or more of remaining fatigue life. The Air Force currently uses RFC to manage part life for several of its gas turbine engines.

Successfully implementing turbine engine component RFC requires automated eddy current inspection stations that locate and measure part defects accurately. Eddy current probes used for performing the inspections require a fast, reliable method for calibrating inspection probe sensitivity prior to each use.

Each part tested requires standard reference samples because, without a standard reference, eddy current inspections are of little value. Each calibration consists of two steps: phase calibration and gain calibration. The phase calibration requires an artifact using the same alloy as the evaluated engine part. The gain calibration requires a sample defect made in a repeatable fashion. Currently, these simulated defects are EDM notches in engine material samples.

Materials Engineers Improve Reliability of C-17 Landing Gear

Payoff Rapid deployment of a fix for C-17 landing gear problems eliminated a major operational and safety concern in the C-17 fleet and will provide the Air Force a cost avoidance of more than $500,000 for each failure eliminated. Elimination of this failure mode also increases mission readiness.

Accomplishment Engineers from the Materials and Manufacturing Directorate, working with members of the C-17 System Program Office and two Safety Investigation Boards, solved a landing gear failure problem on the C-17 aircraft. Their rapid analysis recommended use of the C-17 trunnion collar—a new design that provides fatigue-resistant thread roots.

Background During routine landing of a C-17 aircraft, the main landing gear failed upon impact and folded into the plane's fuselage. Responding to a request from the Safety Investigation Board, engineers from the directorate's Systems Support Division analyzed the landing gear structure to determine the reason for failure.

Analysis included a detailed examination of fracture surfaces using optical and scanning electron microscopes, and energy dispersive spectroscopy. Engineers also performed cross-sectional analysis including dimensional verification, base alloy metallurgical analysis of the chemistry, microstructure and hardness, and a residual stress survey using X-ray diffraction. In addition, they reviewed the manufacturer's processes that would affect the fatigue initiation performance of this component.

Directorate engineers determined the trunnion collar, a mechanism that keeps the 10 ft long, 800 lb gear straight with the wheel well, to be the problem. Threads cut in the trunnion collar, where a fatigue flaw initiated, use a non-standard "buttress" thread cut. Engineers use the buttress cut, designed for axial loads, when the applied loading is primarily in one direction.

Directorate engineers found this type of cut produced a high-stress concentration located at the thread root that causes fatigue crack initiation. To prevent fatigue initiation, the collar required a more uniform stress distribution, so the engineers recommended a larger root radius thread.

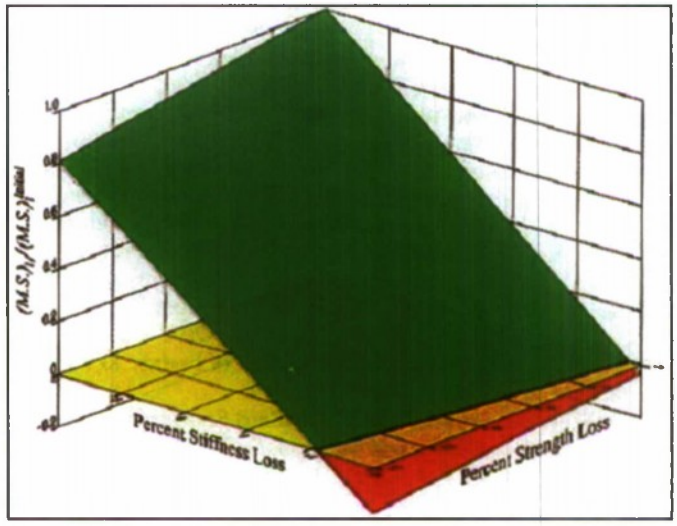
Procedures developed by the materials engineers helped the Air Mobility Command implement the fix on the entire fleet in just six weeks. Long term, the program office will field a further enhanced trunnion collar, incorporating both the gentler root radius threads as well as an increased cross-sectional area.

Predicting the Remaining Useful Life of Composite Aircraft Structures

Payoff Predicting the remaining useful life of composite aircraft components using nondestructive test (NDT) data has operational and economic importance for military and commercial aviation. By accurately identifying the significance and existence of structural deterioration or damage, aircraft maintainers can employ repair resources more intelligently, thus enabling greater efficiency, performance, reliability, and confidence, all at a lower maintenance cost.

Accomplishment Research sponsored and supported by the Materials and Manufacturing Directorate proved the possibility of predicting the residual useful life of advanced composite aircraft structures using NDT data. Aircraft maintainers can apply the analytic framework developed to a broad class of composite aircraft structures to improve the effectiveness and efficiency of composite repair resources and provide substantial reductions in aircraft maintenance costs.

Background Modern aircraft and aerospace vehicles are heterogeneous structures comprised of complex mixtures of composite and metallic materials. Substandard fabrication procedures, environmental exposure and handling, or service damage can all have a negative impact on the mechanical integrity of these structures without affecting their visual appearance.



In composite structures, material discontinuities can consist of delamination, matrix cracking, fiber fracture, voids, porosity, inclusions of foreign objects, and bond failure. Aircraft maintainers consider periodic characterization by various NDT methods an important aspect of ensuring reliable performance for composite components subject to increasingly demanding structural requirements.

Dr. Jocelyn M. Seng, a directorate scientist and engineer, worked with Dr. Raymond J. Nagem of Boston University, and Dr. James H. Williams, Jr. of the Massachusetts Institute of Technology, to combine NDT data with structural design data. They combined this data with material degradation models to formulate a residual life prediction model for the Harrier Jump Jet's horizontal stabilizer.

The team defined the structural integrity state and operational failure criteria for the stabilizer and developed an analytical paradigm for predicting its remaining useful life. The analytic framework developed as a result of the project is applicable to a broad class of composite aircraft structures and could lead to more effective, more efficient use of composite repair resources, extended use of composite structures, and substantial reductions in aircraft maintenance costs.

JASSM Program Completes Successful Series of Sympathetic Detonation Tests

Payoff The Joint Air-to-Surface Stand-off Missile (JASSM) may become the first munition item to obtain insensitive munition (IM) certification and a 1.2.3 hazard classification. Currently, almost all munition items are hazard classified 1.1. This certification and classification reflect improvements in the munition that greatly reduce both the threat for accidental initiation of the item and the severity in case of an inadvertent initiation. The safety implications and reduced costs associated with storage of such IM-compliant munitions are of significant benefit to both the US Air Force and Navy customers.

Accomplishment The JASSM Joint Program Office and Lockheed Martin have something to celebrate. With full support of the Munitions Directorate's Energetic Materials Branch, the JASSM warhead and All-Up-Round passed some of the most difficult tests for obtaining IM certification and a reduced explosive hazard classification (1.2.3).

Background After a disappointing failure of the first JASSM warhead during sympathetic detonation testing, engineers from Lockheed Martin asked the Energetic Materials Branch to analyze the failure. Drawing on previous experience in the development of IM-compliant Mk-82 bombs filled with the newly developed AFX-645 explosive, the directorate recommended a non-standard pallet stacking arrangement. This new stacking arrangement mitigates the energy transferred during sympathetic detonation from one munition to the next.

Lockheed Martin engineers tested this configuration in a hydrocode study and confirmed that the directorate's suggestions did provide a significant improvement for survival. Lockheed Martin further improved this concept by positioning the JASSM warheads side by side in a nose-to-tail configuration. The engineers placed the warhead casings as close as possible, preventing a sympathetic detonation from occuring. Lockheed Martin engineers performed a new test using this storage configuration and successfully passed the sympathetic detonation criterion.

To date, the directorate and Lockheed Martin have accomplished all required IM classification testing, while hazard classification testing is nearly complete. This is a major milestone since it is the first time a major Air Force weapon system has passed all required IM testing.

The Energetic Materials Branch developed AFX-757, the explosive fill used in JASSM, as a replacement for tritonal in the Miniature Munition Technology program. Lockheed Martin, the JASSM contractor, chose AFX-757 for their warhead because of its increased blast energy and potential insensitivity.

MEMS IMU Calibration and Alignment Program

Payoff The Microelectromechanical systems (MEMS) inertial measurement unit (IMU) calibration and alignment (MICA) transfer alignment algorithm benefits any MEMS IMU exhibiting 50-200°/hr gyro drift rates and up to 10°/hr bias in-run stability errors. The algorithm allows an aligned and calibrated MEMS IMU to navigate with accuracy similar to that of a conventional tactical-grade IMU during the weapon's post-alignment trajectory. Improved navigation accuracy provides a technology transition opportunity to weapons programs (like the Wind Corrected Munitions Dispenser program) that require near-tactical grade weapon accuracy for relatively short weapon delivery trajectories.

Accomplishment The Munitions Directorate, in partnership with System Dynamics International, recently completed the first ever F-16 flight tests of a MEMS IMU. The flight tests demonstrated the viability of MEMS IMU technology and the effectiveness of an innovative transfer alignment algorithm called the MICA algorithm.

Researchers designed the MICA algorithm to accurately align the MEMS IMU and substantially calibrate its low-grade (100°/hr) MEMS gyros using data provided by the aircraft's inertial navigation system. The MICA algorithm consists of a conventional integrated velocity-match Kalman filter augmented with yaw attitude-match measurements and two associated filter state variables.

These innovations provide a continuous calibration of the yaw gyro and suppress IMU heading error growth during the low-dynamic cruise segments of the aircraft's alignment trajectory. After a successful series of laboratory and van tests, F-16 captive-carry flight tests demonstrated that the low-grade MEMS IMU, when aligned and calibrated with the MICA algorithm, achieved unaided navigation accuracy comparable to a 5°/hr optical-gyro IMU.

Background AFRL and the Defense Advanced Research Projects Agency are currently pursuing several programs, which specify requirements for small, low-cost IMUs for tactical air-launched weapons. Specifically, investigations are under way to determine the suitability of MEMS sensors and ultimately MEMS-based IMUs for these applications.

Currently, MEMS gyro errors are approximately one to two orders of magnitude larger than those associated with the more mature and costly optical gyro IMUs (e.g., ring laser gyros and fiber optic gyros). For most tactical weapon systems, these large MEMS gyro errors induce prohibitively large weapon miss distances (hundreds of meters), virtually eliminating MEMS IMUs from serious consideration.

Ongoing research efforts to develop a practical 1-10°/hr MEMS gyro are several years away from completion. However, the Air Force recognized near-term MEMS IMUs as viable candidates for tactical weapon systems if researchers developed an advanced algorithm to reliably calibrate and align the MEMS IMUs during prelaunch transfer alignment. This approach provides a software solution to a current hardware limitation, thereby allowing system designers to use small, low-cost MEMS IMUs without sacrificing weapon system performance.

Instrumented Reusable Blast Pad Provides Reliable Data

Payoff The Munitions Directorate, located at Eglin Air Force Base, Florida, completed the design, fabrication, and assembly of a unique, highly instrumented, reusable blast pad. Innovative features incorporated in the blast pad allow directorate engineers to obtain blast pressure measurements reliably in blast environments characterized by high-intensity pressure loads and severe fragmentation. Munitions engineers need these measurements to develop explosive source models more representative of realistic Air Force munitions, a critical aspect of simulation tools used for warhead designs of the future.

Accomplishment The data from blast pad experiments will provide more accurate explosive source models to Air Force simulation tools. As a direct result, directorate engineers will perform Air Force simulations of concept and inventory munitions with explosive source models that place more accurate blast loads on targets. Engineers will perform concept evaluations, analyses of alternatives, and other studies of munitions effectiveness with greater confidence of predicted structural damage.

The instrumented blast pad will also support other explosive and warhead development efforts at the directorate. By locating the blast pad, the directorate capitalized on the existing range infrastructure and workforce. The directorate continues its munitions development cost reduction pursuits by improving the ability to simulate innovative warhead designs instead of relying on expensive full-scale experiments.

Background Directorate personnel conceptualized a new and innovative experimental approach for characterizing the blast output of realistic munitions by constructing a special blast pad that incorporated features needed for cased explosive charges, yet closely approximated a classic hemispherical surface burst experiment. This apparatus, referred to as the instrumented blast pad, consists of a 140 ft by 80 ft by 8 in. thick concrete slab with a specially designed replaceable detonation area.

Directorate engineers can reliably measure blast pressures and arrival times regardless of the nature of the explosive source tested. Experiments with the instrumented blast pad should provide detailed characterization of the blast environment from realistic cased charges (e.g., munitions or warheads) without the analysis problems posed by traditional arena tests.

TECH CONNECT - AFRL's Technology Information Clearinghouse

Payoff From the maintainer on the flight line to overseas logistics directors, TECH CONNECT finds information quickly for customers who can submit queries by phone, email, in person, or at conferences/displays. Customers report an average savings of 61 hours of research each time they use this service. TECH CONNECT searches a number of federal databases and the World Wide Web, and has strong ties to the technology transfer effort, using the technology transfer focal points as their primary contacts within the AFRL directorates.

Accomplishment TECH CONNECT relies upon the expertise of scientists and engineers in AFRL who may have novel solutions to answer technology needs. However, TECH CONNECT also assists AFRL personnel.

TECH CONNECT can research ongoing Department of Defense (DoD) efforts, using Air Force sources as well as Army and Navy, through Tri-Service Network (TriNET), an e-mail network to share science and technology information. TriNET encourages rapid teaming to help satisfy common requirements, enhances rapid responses to requested technology information needs, shares technology information, and reduces the workload involved in finding technical area experts.

For example, a logistics contractor with the Aeronautical Systems Center wanted information on aviator night vision compatibility testing. TECH CONNECT sent a TriNET message to DoD and received input from the Army Night Vision Office at Fort Belvoir, Virginia, the Naval Aircrew Systems Office in Patuxent River Maryland, and several other government agencies (AFRL/MLP, AFRL/HEC, ASC-YF, and WR-ALC/TIE). In another request, a FedEx customer wanted information on pilot selection and performance capability. TECH CONNECT received feedback from the Navy with points of contact at Pensacola's Operational Medical Institute and the Naval Aerospace Medical Research Laboratory, from the Army science advisor at Fort Hood with points of contact for both fixed and rotary aircraft, from AFRL/DE, and from the University of Florida's Gulf Coast Alliance for Transfer.

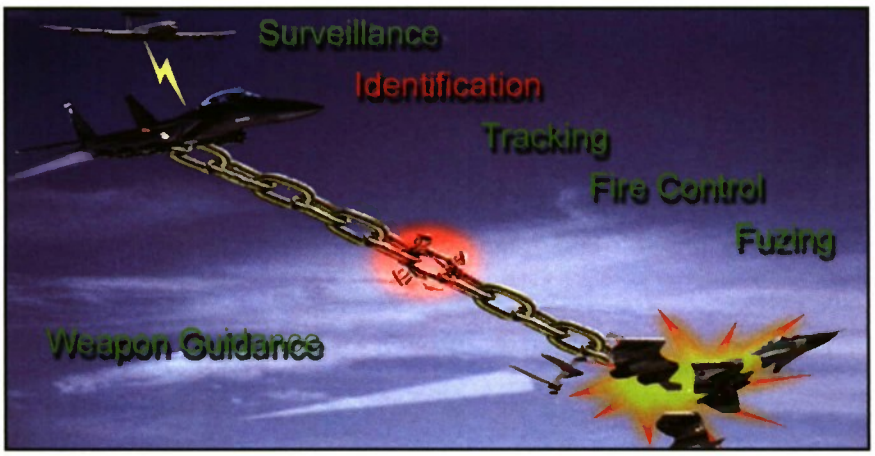
Background TECH CONNECT averages over 1,500 requests per year. About 30% come from DoD, 5% from academia, and 65% from the private sector. Any company, academic institution, or business may contact TECH CONNECT to locate a scientist or engineer who can answer questions on the desired technology, or learn about specific technology opportunities.

TECH CONNECT is the contact point for AFRL Success Stories and AFRL's quarterly magazine, *Technology Horizons®*. TECH CONNECT provides customers with additional information on articles in the magazine and available literature. The TECH CONNECT office, located within AFRL/XP at Wright-Patterson AFB, Ohio, provides this service free of charge. For more information, call (800) 203-6451, DSN 986-9030, e-mail afteccon@wpafb.af.mil, or visit the web site: *http://www.afrl.af.mil/techconn/index.htm.*

Radar-Based Target Identification Capability Developed for AWACS

Payoff Current identification (ID) capabilities, combined with restrictive rules of engagement, often result in very limited ID ranges, which limit weapons engagement ranges. The technical breakthroughs achieved in the radar-based target capability identification (RTCID) effort and their application to the E-3 Airborne Warning and Control System (AWACS) radar system provide reliable target ID at significant target ranges. Such long-range target ID information is available in real time to fighter aircraft for more effective use of advanced medium-range air-to-air missile and improved overall combat effectiveness of current and future Air Force weapons systems.

Accomplishment Sensors Directorate engineers, working with Northrop Grumman's Electronic Sensors and Systems Sector, and their subcontractor, JJM Systems of Jamison, Pennsylvania, developed a long-range, non-cooperative target ID capability for the AWACS aircraft. Directorate engineers flight tested RTCID at the all-service combat identification evaluation team (ASCIET) exercise. The Information Directorate's Hostile Target ID program sponsored this advanced technology demonstration (ATD).



Background Fire control-type radar systems historically performed target ID functions. The Air Force expressed an interest in adding a radar-based, non-cooperative target identification (NCTI) capability to the E-3 AWACS. Recent conflicts and ASCIET testing demonstrated both a lack of adequate target ID capability and the value of adding such a capability to surveillance and command and control systems.

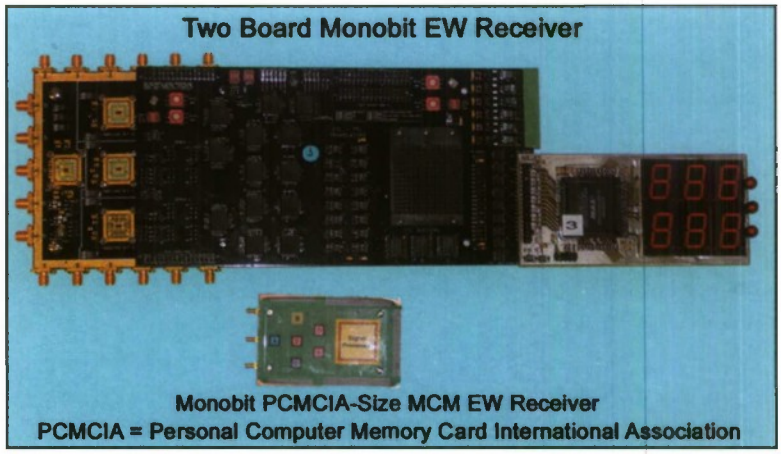
Past efforts investigated the addition of various target ID techniques for AWACS with limited success. This ID solution does not impact radar performance and uses existing modes of the radar. The RTCID ATD provides both a method and architecture for adding an NCTI capability to the AWACS, while providing a timely, high-confidence ID source for fusion with other onboard and offboard sources of ID information.

Low-Cost Digital Electronic Warfare Receiver

Payoff Scientists at the Sensors Directorate designed and developed Monobit, an affordable cueing receiver, which processes and detects simultaneous signals to enhance situation awareness. This new design uses a cost-effective and reprogrammable field programmable gate array. The multiple-chip module (MCM) design integrates all the components, greatly reducing size, weight, and power. The Monobit receiver improves and upgrades the performance of tactical; strategic; intelligence, surveillance, reconnaissance; and space systems to improve warfighting capabilities.

Accomplishment Directorate scientists demonstrated a low-cost digital electronic warfare (EW) receiver that processes two simultaneous signals in 1 GHz bandwidth. This new receiver, manufactured on a single MCM, will provide 20 times the reduction in weight, 10 times the reduction in power, and less than 1% false alarm rate with improved reliability.

Background In EW, a broadband radio receiver, such as the instantaneous frequency measurement receiver, senses a target by intercepting an incoming radio frequency (RF) signal. Directorate scientists designed and developed a new, unique, and simple-to-implement EW receiver called the Monobit receiver. The hardware consists of an RF front-end, analog-to-digital converter; de-multiplexer; and a signal-processing chip.



This new digitized EW receiver handles two simultaneous signal sources and provides the operator with information indicating detection of a hostile signal. The basis of the receiver is real-time application of the discrete Fourier transform mathematical function with a single binary-bit kernel function. The Fourier transform, accomplished through the mathematical operations of addition and subtraction, eliminates the multiplication operation and enables much higher speed signal-processing.

Real-Time Infrared Scene Simulator Transitioned and Commercialized

Payoff The Real-Time Infrared Scene Simulator (RISS), a Small Business Innovation Research (SBIR)-funded breakthrough, provides simulation technology for rapidly implementing software modifications to infrared missile warning receivers and significantly reduces response time and cost for meeting urgent operational needs. RISS is a new core simulation technology that revolutionizes the Air Force methodology for developing software changes for electro-optical missile warning receivers.

Accomplishment Under the Air Force SBIR program, the Sensors Directorate developed, demonstrated, and transitioned real-time hardware-in-the-loop simulation technology enabling Warner-Robins Air Logistics Center (WR-ALC) to meet critical United States Special Operations Command (USSOCOM) mission needs. This technology is the result of highly successful leading- edge SBIR research by Amherst Systems, Inc. of Buffalo, New York. Amherst Systems' engineers commercialized this pioneering SBIR technology breakthrough as one of their standard simulator products for the development and integration of electro-optical missile warning receivers for Department of Defense weapon systems.

Background The Electronic Warfare Branch applied two SBIR Phase II initiatives with their Integrated Defensive Avionics Laboratory to a USSOCOM special operations force need for a rapid prototyping capability to modify infrared missile warning receiver software. The Electronic Warfare Branch worked with the WR-ALC Electronic Warfare Management Directorate's Special Programs Engineering Branch and the SBIR contractors to form a government/contractor integrated product team to transition this SBIR technology and meet the urgent USSOCOM need.

This team's effort resulted in the development and transition of RISS, enabling WR-ALC to develop their Missile Warning Receivers Integrated Support Station, a revolutionary concept for rapidly modifying the software of electro-optical missile warning receivers. This technology provides an unprecedented cost-effective capability for developing and implementing these software changes in a laboratory environment through high fidelity hardware-in-the-loop simulation, significantly reducing the requirements for flight test.

Mobile Test Van Adds New Testing Capabilities

Payoff The mobile test van is a proven autonomous, stand-alone system that is a valuable resource capable of generating coherent and non-coherent electronic attack signals. Technicians can set up the test van in nearly any terrain. Technicians can tailor the van, a flexible and dynamic system, to nearly any test conditions required. At a reasonable cost, the test van is adept for quick reaction or long-term tests.

Accomplishment Engineers at the Sensors Directorate developed a mobile test van to assist in evaluating electronic warfare techniques. The van is a self-contained resource that generates a variety of electronic signals simulating battlefield conditions. Technicians can configure the test van to provide a diverse array of electronic attack techniques including non-coherent noise, coherent noise, and coherent false targets. With this type of capability, engineers can perform numerous tests with the van on any terrain at a reasonable cost.

Background The environment of electronic warfare is continuously evolving. Directorate engineers need quick and accurate simulations of a variety of jamming and waveform systems to accurately test new electronic warfare techniques. The directorate developed the test van to perform these difficult tasks.

The self-sufficient mobile van generates a variety of electronic warfare techniques. It is also highly configurable for multiple roles including generating synthetic coherent targets, coherent jamming, transponder jamming, noise jamming calibration targets, and radar parameter characterization.

Housed in a standard Ford truck, the van operates as a stand-alone system qualified to produce frequency coverage from high frequency to Ku bands for applications ranging from air-to-ground, ground-to-air, space-based or laboratory-based systems. In addition, man-portable generators are available for autonomous repeater operation that is either synchronous or nonsynchronous to the radar pulse repetition frequency.

Automated Method to Build Technical Data Packages for Competitive Procurements of Spare Parts

Payoff By providing the Defense Logistics Agency (DLA) with technical data packages, the Department of Defense (DoD) can now outsource the assembly of critical spare parts. Critical parts can be obtained faster, cost less, and possess improved quality because the technical data packages contain accurate information for the manufacturers. The Technical Data Strategy program successfully decreased the number of nonexistent and incomplete technical data packages in a six-month period.

Accomplishment Under contract with the Sensors Directorate, Altech Services, Inc. developed conversion and management software for procuring critical spare parts. Using Standard for the Exchange of Product Model Data (STEP), DLA will build initial technical data packages for competitive procurements of spare parts.

This program also allows DLA to obtain missing data from the Joint Engineering Data Management Information Control System (JEDMICS) database. Without these technical data packages to procure new spare parts, many aging aircraft would lack the necessary parts to fly.

Background Several years ago, the DLA assumed responsibility from the Air Force Materiel Command for procuring spare parts for all weapon systems in the DoD. Aging aircraft and the unwillingness of the original equipment manufacturers to manufacture replacement items, components, and parts exacerbated the problem. DLA requested assistance from the directorate in analyzing and possibly automating the current technical data package process.

Teaming with Altech Services, Inc. and the Air Logistics Center in Oklahoma City, Oklahoma, directorate engineer Ms. Janice Chinn (pictured) used automated tracking, MetaPhase® metrics capturing, and STEP data transferring to begin building and reconstructing technical data packages for procurement of spare parts. The directorate's goal over a 12-month period was to compile and complete a total of 90 technical data packages for the bidding and procurement process. During the first month, 52 technical data packages containing 2,860 images were consummated. To date, the directorate completed a total of 2,519 technical data packages for procurement of spare parts for DoD warfighters. The automated methodology to reconstruct and build initial technical data packages, and obtain the required missing data from JEDMICS and manufacturers is significantly beneficial to the Air Force E-3, B-1, B-52, and C/K-135 aging aircraft. As a result of this test program, engineers reduced the average cost to build a technical data package by more than 50% (from $1050 to $500) per package—a savings of over $1.3 million.

The Integrated Precision Synthetic Aperture Radar Targeting System

Payoff The Integrated Precision Synthetic Aperture Radar Targeting (IPSART) system is a user-friendly system that allows researchers to design, analyze, and develop synthetic aperture radar (SAR) targeting techniques with greater precision and at a faster rate. In addition, IPSART is a learning tool for users with various levels of radar experience. Engineers can use this tool to perform collaborative work with other agencies and laboratories to produce new technologies and improve current capabilities in multiple disciplines.

Accomplishment Researchers at the Sensors Directorate developed IPSART, an innovative design tool for modeling and analysis of airborne radar system performance for precision SAR targeting. IPSART allows research and development organizations at various locations to perform collaborative engineering.

Background High-resolution SAR targeting capability is vital for precision-strike mission success. In difficult electronic countermeasure environments, increasingly sophisticated enemy defenses require fire control information derived from highly maneuverable aircraft trajectories rather than traditional straight-and-level flight.

These imaging and targeting conditions impose severe performance requirements on the sensor's aircraft motion compensation system and dictate the need for sophisticated algorithms to counteract the electromagnetic compatibility threats. The IPSART system develops a high fidelity end-to-end simulation for realistic SAR targeting in a hostile environment for a highly maneuverable tactical aircraft.

In order to simulate a complex environment, this system must model a spotlight SAR, a trajectory generator, and coherent jamming. IPSART generates synthetic images, which will allow software designers to determine the best method in designing, developing, or analyzing SAR targeting capability on current or new SAR systems.

The IPSART tool uses the Cantata graphical user interface to provide user-friendly operations for a large number of researchers and support a variety of experiments. Cantata is a data flow visual programming language, which enables the developer to generate a workspace by connecting several functional modules to form a data flow graph.

Defense Meteorological Satellite Program CRADA

Payoff The Space Vehicles Directorate and Northrop Grumman Corporation recently signed a $9.103 million Cooperative Research and Development Agreement (CRADA) to provide research and development capabilities for the Defense Meteorological Satellite Program (DMSP) environmental sensors and to help assure continuity of mission support to the warfighter.

Accomplishment The results of this research will address the needs of both commercial technology and the Department of Defense (DoD) by advancing state-of-the-art satellite communications systems. This CRADA is one of the largest research initiatives in terms of dollars within the Air Force.

Background Recently, the DMSP System Program Office assigned total system performance responsibility for the DMSP space sensors to Northrop Grumman. The directorate will provide continued technical support and services to the DMSP through this CRADA. The Air Force and Northrop Grumman expect to benefit from the relationship and the resulting shared data.

The Air Force benefits include optimally sustaining the DMSP throughout its mission lifetime, compliance with DMSP developments with the Space Weather Transition Plan, and seamless transition of space weather support to the next-generation National Polar-orbiting Operational Environmental Satellite System. Northrop Grumman will benefit by allowing the combined technical staffs to develop and deploy advanced earth-monitoring space sensors in coordination with DoD needs.

Emerging Technologies

Continued on next page...

Emerging Technologies

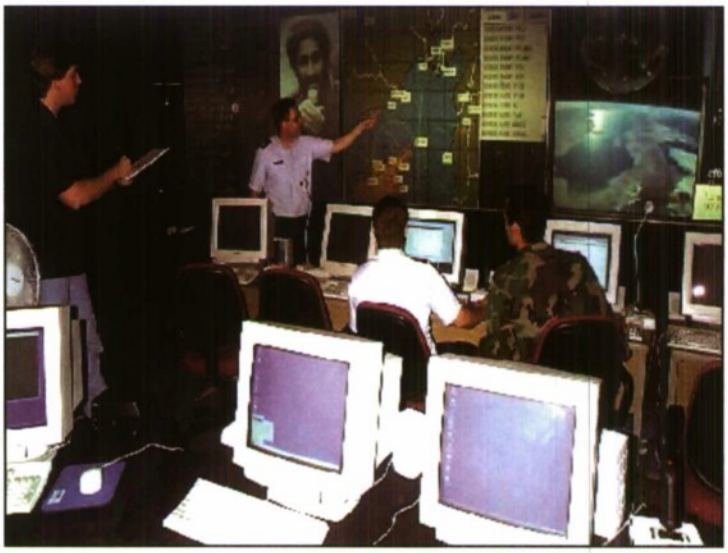
Quantifying Human Performance Achieves New Accuracies

Payoff Newly created Synthetic Task Environments (STEs) can more accurately measure a person's performance in the workplace. Now for the first time, scientists can use STEs to compare results of varied influences on Air Force individual and team performance.

Accomplishment The Air Force Office of Scientific Research's Chemistry and Life Sciences Directorate and the Human Effectiveness Directorate funded the research for this landmark measuring tool. The Warfighter Training Research Division in Mesa, Arizona, and the Information Systems Training Branch at Brooks AFB, Texas, accomplished the research from 1996 to the present.

Background The STE approach observes the effectiveness of Air Force personnel on the job and encompasses a complex array of tasks. The STE gives researchers a flexible tool to gather useful data in areas previously thought difficult and measure computer-aided instruction, human-computer interfaces, team member interactions, and training interventions.

As a result of the findings, directorate researchers established a real-time collaborative team research program on the Internet for government, university, and small business participation to expand these results into information fusion, distributed decision making, and human representation modeling. Researchers tested the STEs by analyzing the tasks involved in operating unmanned air vehicles and observing Air Force experts perform command and control functions in airborne warning and control aircraft.



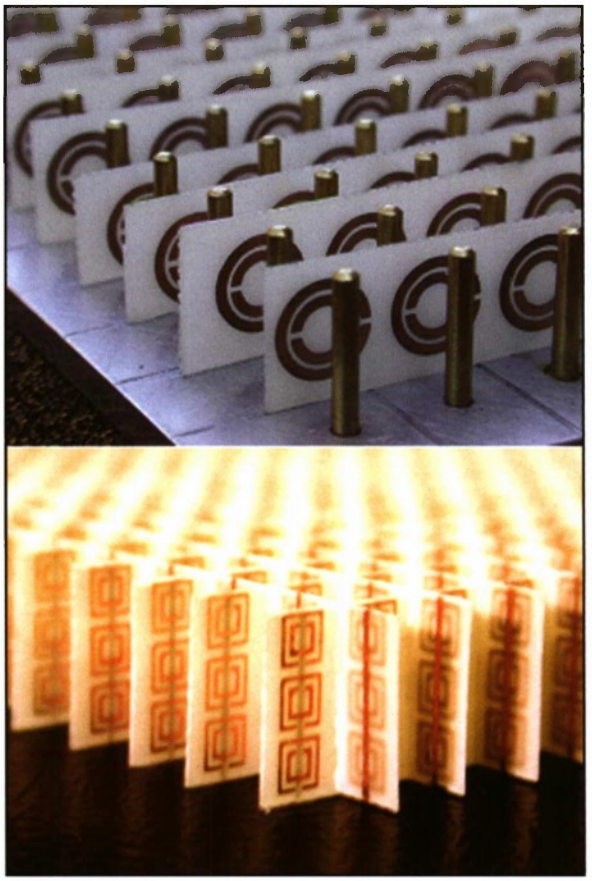
Based on the findings, the researchers formulated computer-based simulations of operational scenarios and established a benchmark for human performance called Human Performance Units (HPUs). HPUs enable experts to make scientific recommendations on how to improve a worker's performance and the impact of new technology in the workplace.

New Class of Composite Materials

Payoff A new material could prove useful in improving communication by developing new optical lenses, novel antennas and filters, and other electromagnetic devices. It may even make possible the construction of a "perfect lens," capable of focusing light and other forms of radiation to limits not achievable by normal lenses. These advances would offer significant advantages to many Air Force applications.

Accomplishment Funding from the Physics and Electronics Directorate of the Air Force Office of Scientific Research and the Defense Advanced Research Projects Agency supported a team of physicists from the University of California, San Diego (UCSD), who verified predictions for a new class of composite materials. Last year, researchers produced these composite materials believing they would exhibit behaviors opposite of many fundamental properties commonly associated with composites.

Background Drs. Richard Shelby, David Smith, and Sheldon Schultz at UCSD tested earlier theoretical predictions of new electromagnetic properties. After building a prototype of their proposed composite from fiberglass and tiny copper wires, the researchers sent microwaves of the same frequency used in police radar guns through the material. The microwaves emerged from the sample with a deflection opposite to that predicted by Snell's law for ordinary materials, thus confirming the predictions.



Snell's law describes the angle of refraction—the angle through which light and other forms of electromagnetic radiation are deflected on entering water, glass, and other ordinary materials. Physicists refer to the parameter that determines the degree of deflection caused by a material as its index of refraction. Normal materials have a "positive" index of refraction, associated with a deflection produced by the slowing of light on entering the material.

When radiation enters the new class of composite materials produced by UCSD researchers, it is bent in the opposite direction, equivalent to exhibiting a "negative" index of refraction. Since no existing composite has this property, the UCSD scientists demonstrated the effect using a metamaterial—a composite material fabricated from repeated elements, specifically engineered to produce the desired electromagnetic behavior.

Engineers use the deflection of light by materials, coupled with curved and patterned structures, such as lenses and gratings, for controlling electromagnetic radiation in optical and microwave systems. Currently, all optical systems are based on materials with a positive index of refraction. The introduction of materials with a negative index offers the potential for radically different designs in optical and microwave systems of the future.

Atomic Structure Models Provide Link to Predictions of Properties of Materials

Payoff The Air Force Office of Scientific Research sponsored research to verify the accuracy of a model that predicts certain aspects of the deformation behavior of metals. This discovery will allow the Air Force to vastly decrease the scope, duration, and cost of testing materials used in weapon systems.

Accomplishment Since 1998, the Metallic Materials program in the Aerospace and Materials Sciences Directorate funded two universities involved in the determination of atomic core structure of dislocations in various metals. First, Professor Arthur Freeman and his colleagues at Northwestern University, created a first-principles model that forecasts the atomic core structure of dislocations in gold and iridium.

Then, using high-resolution transmission electron microscopy, Professor Kevin Hemker and associates at Johns Hopkins University, achieved direct resolution of dislocation cores in gold and iridium. Professor Hemker's team proved that previous calculations by Professor Freeman's group accurately forecasted atomic positions around dislocation cores for several different dislocation configurations.

Background Many useful engineering properties of materials depend on the type and distribution of defects in the arrangements of their atoms. Scientists rely on experiments to establish and validate materials, databases used in design, and selective use of computations, using physically based models to vastly decrease the scope, duration, and cost of experimental programs.

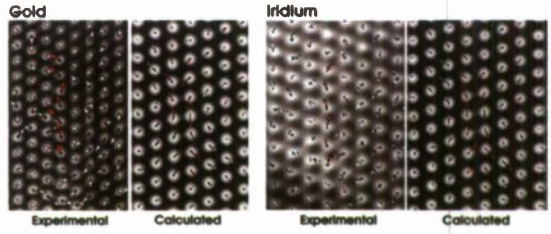
This computational strategy provides the foundation for programs leading to shorter design cycles that incorporate optimized techniques for materials selection and processing, resulting in more affordable and reliable weapon systems. Dislocations are the principal crystal defect responsible for permanent changes in the shape of crystalline materials.

Atomic models of dislocations, based on quantum mechanics, provide the necessary information to explain and predict differences in the deformation behavior of various metals. This information forms the basis for computational models that relate the behavior of a material to its thermo-mechanical environment, thus permitting computations of structure and property changes during processing and service.

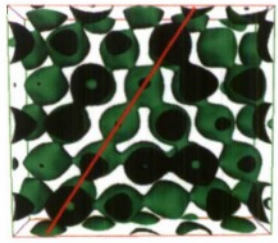
Experimental verification of structures, based on models, increases confidence in the prediction of other properties that are more difficult to measure. Researchers at the Materials and Manufacturing Directorate developed a hybrid model that couples discrete and continuum descriptions of the crystal to calculate dislocation core structures in molybdenum.

Results of current research at Johns Hopkins will extend the capability for linking deformation behavior of these metals to their atomic structure. This will expand the capability for constructing accurate models for the design of materials and reduce costs of new materials.

Images of Screw Dislocation Cores in Gold and Iridium



Iso-charge density plot showing atomic locations around the core of a screw dislocation in Molybdenum



AFOSR Funds the Development of a Self-Healing Plastic

Payoff Researchers recently reported significant progress in the development of a self-healing plastic. The material could increase the reliability and service life of thermosetting polymers used in a wide variety of applications ranging from microelectronics to aerospace. The payoff of this research to the Air Force (AF) could be significant because of the many polymer-based composites in AF aircraft.

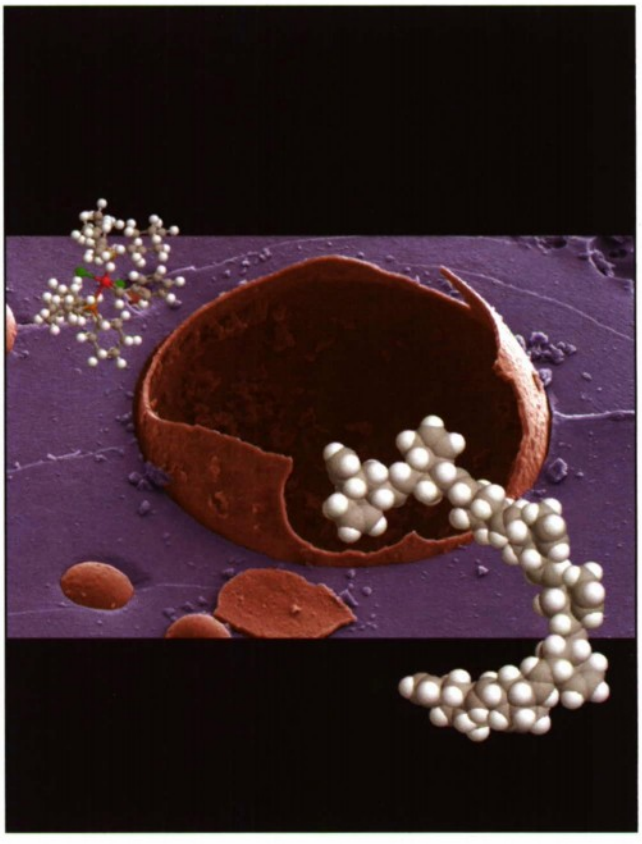
Accomplishment Air Force Office of Scientific Research (AFOSR)-sponsored researchers at the University of Illinois at Urbana-Champaign (UI) developed a synthetic material that can heal itself when cracked or broken. The research team, inspired by biological systems in which damage triggers an autonomic healing response, embedded a microencapsulated healing agent and a special catalyst in a structural composite matrix.

Frequently, structural damage in the form of microcracks develops deep within the aircraft where detection is difficult and repair becomes almost impossible. However, with this potential new material, the repair process would begin as soon as a microcrack forms, resulting in more durable aircraft/spacecraft.

Background Dr. Scott White and his UI team received initial and some follow-on funding from a UI Critical Research Initiatives grant. In 1999, AFOSR's Aerospace and Materials Sciences Directorate awarded the UI research team a three-year grant.

When a material cracks, the microcapsules rupture and release the healing agent into the damaged region through capillary action. As the healing agent contacts the embedded catalyst, polymerization initiation bonds the crack's face closed. Because microcracks are the precursors to structural failure, the ability to heal will enable structures to last longer and require less maintenance.

Filling the microcracks may also mitigate the harmful effects of environmentally assisted degradation such as moisture swelling and corrosion cracking. This technology could increase the lifetime of structural components, perhaps by as much as two or three times. Additionally, the ability to self-repair and restore structural integrity could extend the lifetimes of printed circuit boards where microcracks can lead to both mechanical and electrical failure.



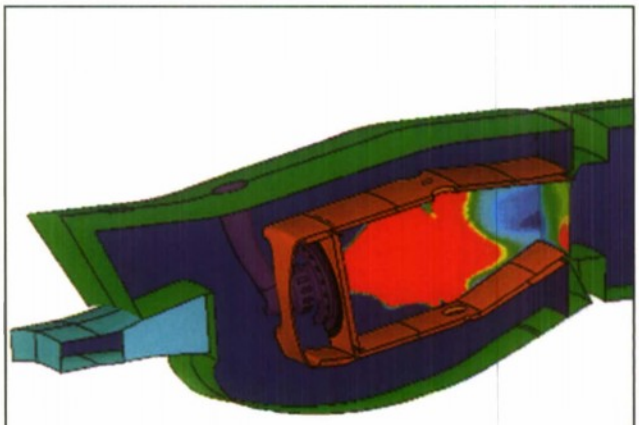
Improved Jet Engine Design from Soot Research

Payoff The Air Force Office of Scientific Research (AFOSR) supported research that produced a computational model for the prediction of soot emissions from gas turbine combustors. This technology led to improved jet engine design, resulting in significant advancements in environmental emission standards.

Accomplishment Under AFOSR's Aerospace and Materials Sciences Directorate support, Dr. Meredith B. Colket III, of United Technologies Research Center (UTRC) in East Hartford, Connecticut, along with Mr. Robert J. Hall of UTRC, and Professor Mitchell D. Smooke of Yale University, formulated a dual-phase model for soot production. This model incorporates (1) gas-phase chemistry to describe the progressive growth of gaseous hydrocarbon molecules to form incipient soot particles, and (2) aerosol dynamics to predict the agglomeration of these initial soot particles into larger particles found in engine combustor environments.

Background Arguably, emissions represent the most stringent test of engine design capability. Turbine engines produce trace amounts of soot and nitrogen oxide emissions in combustors relative to the mass flow rates of fuel and air. However, these small amounts can cause serious damage to engine components and are stringently regulated due to their adverse environmental impact.

Engine manufacturers, such as Pratt and Whitney, face these challenges for both military and commercial engine designs. For example, Pratt and Whitney's 2037 engine, used for commercial transportation systems like the Boeing 757 aircraft, is also the basis for the F117 engine that propels the Air Force C-17 cargo plane.



Computational Model of Soot

Computational tools are essential elements of gas turbine design as the only cost-effective means to achieve preeminent design objectives. However, because of limitations in both computational capability and basic physical understanding, computational design methods were limited to qualitative screening of alternative combustor configurations.

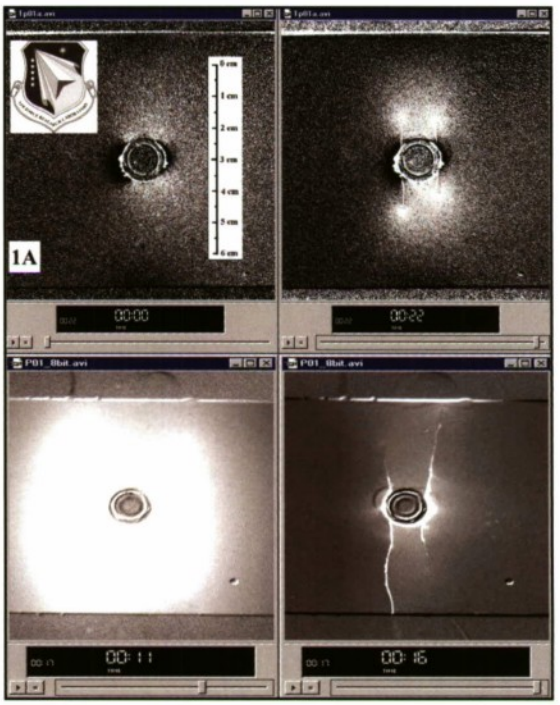
Future Department of Defense performance requirements, as elucidated in the advanced phases of the Integrated High Performance Turbine Engine Technology and the Versatile Affordable Advanced Turbine Engine programs, will necessitate new designs that will surpass evolutionary strategies relative to current engine designs. AFOSR research addressed both computational software and physicochemical deficiencies in order to produce quantitatively accurate computational design methodology.

Dr. Saadat Syed, a Pratt and Whitney Fellow in combustion, recognized the accuracy and computational efficiency of this model and incorporated a streamlined version into the design methodology for the Pratt and Whitney 6000 aircraft engine. Based on the test results, Pratt and Whitney projects this engine to comply fully with existing International Aviation Organization emission standards.

Visual Crack Measurement System

Payoff Structural failures in secondary structures plague aging US Air Force aircraft. The Visual Crack Measurement System (VCMS) allows researchers to view the crack growth in those structures relative to vibration. This research is invaluable to the fleet of Air Force aging aircraft. VCMS is useable on composite, as well as aluminum, structures and opens the door for commercial applications.

Accomplishment The Air Vehicles Directorate successfully developed the VCMS, which uses temperature sensitive paint (TSP) to view and measure cracks on a vibrated structure. The VCMS records the images of fatigue-induced crack growth using a digital camera on a personal computer. This is the first time researchers obtained plots of crack length versus cycles for vibrating plates.



Background A major issue for aging aircraft is structural failure in secondary structures. Cracks appear in secondary structures due to turbulent aerodynamic flow, exhaust flow, and high acoustic environments. The directorate developed a way to reliably slow or stop the crack growth through bonded composite repairs with added damping to reduce the vibrations that cause the stresses that, in-turn, cause the cracks. However, knowing where and when to place the repair on a secondary structure remained an issue.

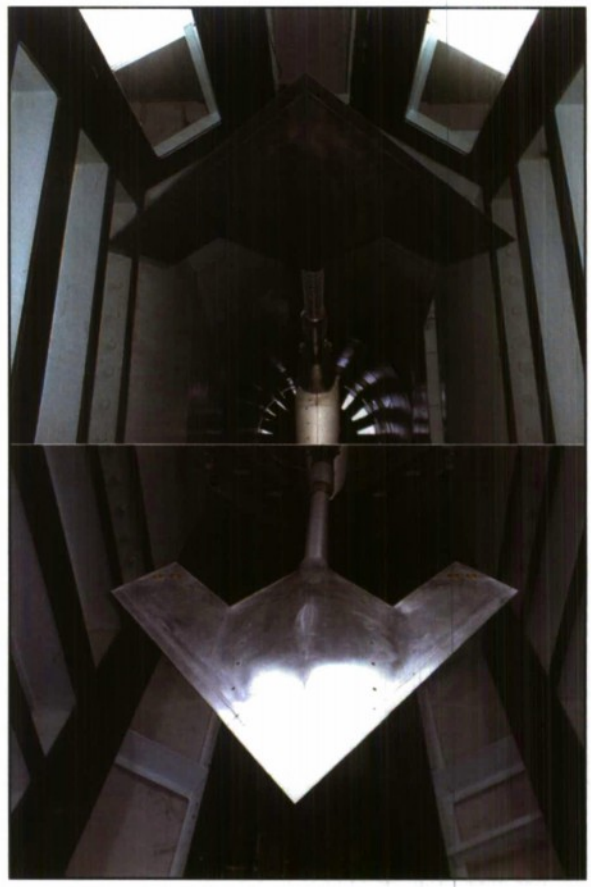
Directorate researchers resolved that issue through successful use of the VCMS. They conducted an experiment to assess the reduction in fatigue crack growth in secondary aircraft structures with and without bonded damped fiberglass repair patches. Researchers used eight completely cracked plates to determine the effects of no patching. They used another 12 plates, cracked to a length of approximately 25 mm, and tested them with patches of structural adhesive, visoelastic material, and fiberglass. The researchers then used VCMS and TSP to observe crack growth.

SARL Wind Tunnel Operational

Payoff The Air Vehicles Directorate's Aeronautical Sciences Division recently repaired the Philip P. Antonatos Subsonic Aerodynamic Research Laboratory (SARL) wind tunnel in-house for a significant savings. Returning this one-of-its-kind wind tunnel to operational status allows Air Force researchers to perform valuable research and development testing.

Accomplishment The directorate successfully repaired the SARL wind tunnel, permitting airflow through the tunnel under its own power. This is the first time the wind tunnel operated in over two years.

The SARL is the newest of the wind tunnels at Wright-Patterson Air Force Base (WPAFB), Ohio. It allows 360° optical access and facilitates high angle-of-attack simulation that cannot be completed elsewhere. This wind tunnel allows simulations at speeds of Mach 0.15 to Mach 0.6 (approximately 100 to 450 miles per hour) and accommodates models with up to a 3½ ft wingspan.



Background The Philip P. Antonatos SARL wind tunnel, named for former Aeromechanics Division Chief Philip Antonatos, is the newest of WPAFB's wind tunnels. This wind tunnel began with motor and gearbox shakedown, followed by testing two years later. The SARL is an open circuit subsonic wind tunnel run by a 20,000 horsepower motor. The directorate designed the facility to maximize flow visualization, with 55% of the test sections constructed of optical quality Plexiglas® panels that allow the all-around visibility of the test subject.

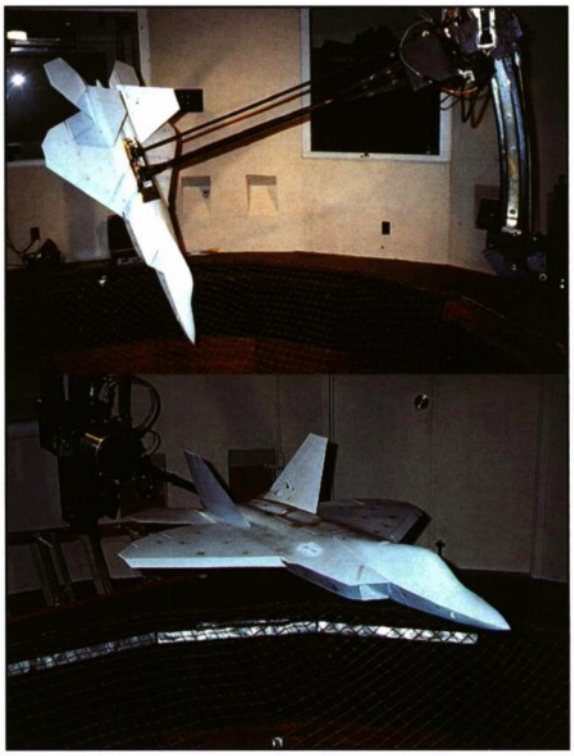
In 1998, the SARL wind tunnel suffered a failure of the advanced model support arc bearing system. Directorate engineers used temporary supports to complete the test season. However, testing that required the support system to rotate/pitch or allow high angle-of-attack was impossible without the advanced model support.

Months later, directorate engineers began disassembling and removing the 16-plus ft arc sector, weighing over 2.5 tons. The directorate was unable to use the SARL wind tunnel again until completing the necessary repairs.

Vertical Wind Tunnel Can Now Test Realistic Aircraft Maneuvers

Payoff A new combined motion test capability demonstrated by the Air Vehicles Directorate at Wright-Patterson Air Force Base, Ohio, will significantly enhance the evaluation and modeling of future highly agile aircraft. This expanded test capability will also result in a reduction of required test time and a corresponding cost savings.

Accomplishment The directorate recently demonstrated a new combined motion test capability using a multi-axis test rig in its vertical wind tunnel (VWT). The combined motion capability identifies the traditional roll, yaw, and wind axis motions. Combining a roll or yaw body axis test motion with a rotation about the wind axis rotation achieves virtually any motion combination.



Background The ability to simulate and model the aerodynamic forces and moments generated on highly agile aircraft in maneuvering flight is difficult. Past efforts only collected data during rotation of a model around a single vehicle axis. During an actual aircraft maneuver, however, the vehicle's axis of rotation is continually changing.

No existing rig generated the motion of a true maneuver, and researchers could only study idealized maneuvers using actual wind tunnel test data. The original multi-axis test rig in the VWT, built with several types of motion capability, used only one type of motion at a time.

Under a United States Air Force-funded Small Business Innovation Research program, Bihrle Applied Research of Hampton, Virginia, modified the rig to simultaneously combine two types of motion. This allowed the rig to simulate virtually any maneuver.

Adaptive Optics Experiment Completed

Payoff The Directed Energy Directorate recently completed an adaptive optics experiment at the directorate's North Oscura Peak site in the northern portion of the United States Army's White Sands Missile Range. The experiment demonstrated how a beam-control system could transmit a laser beam over a long, nearly horizontal path to a moving target. The system also corrected for the distorting effects of optical turbulence in the atmosphere. If unchecked, optical turbulence could limit the range and effectiveness of a laser.

Accomplishment Directorate engineers designed the Dynamic Compensation experiment to replicate the functionality of the beam control system on the Airborne Laser (ABL). The experiment will help keep the ABL program on track by validating its beam control design against non-cooperative targets. An improvement factor of 5 to 20 between the uncompensated and compensated laser spots on the target was noted. This unprecedented performance in strong turbulence will pave the way for many future directed energy applications.

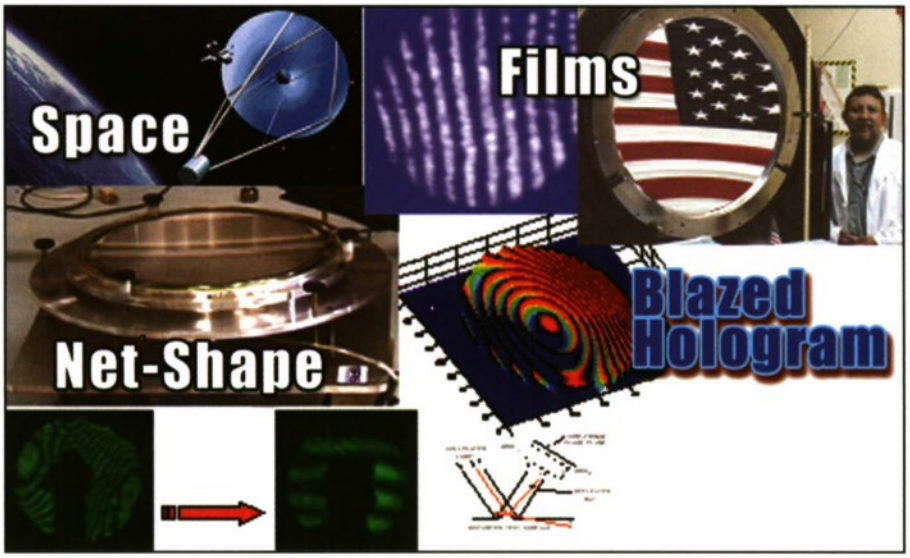
Background The directorate uses the North Oscura Peak site to conduct research for improving the Air Force's ability to track and apply laser energy to destroy missiles. This research benefits the ABL, which uses a laser aboard a jumbo jet to destroy theater ballistic missiles hundreds of miles away.

Facilities at North Oscura Peak house a 1-meter telescope and a beam director that projects a 10-watt scoring laser toward various targets. The experiment used targets located at a static site, such as Salinas Peak—approximately 35 miles south of North Oscura Peak, or moving targets on a Cessna Caravan aircraft with an instrumented target board. North Oscura Peak also has state-of-the-art tracking and adaptive optics systems that correct the outgoing laser beam for the effects of atmospheric optical turbulence.

Large Membrane Optics and Compensation Program

Payoff The Large Membrane Optics and Compensation program encompasses enabling technologies critical to the development of ultra lightweight, large aperture, and space-based optical systems. Several Air Force missions, such as beam projection, surveillance, remote sensing, communications, and imaging, require very large optical apertures in space. The ability to perform all these missions will provide affordable "virtual global presence" by earth observations and force enhancement for the warfighter on demand. The ability to reduce the launch weights and compact packaging of the optical system in smaller launch vehicles will drastically reduce future costs.

Accomplishment The Directed Energy Directorate built and tested a one-meter-class optical membrane mirror in the laboratory. Directorate engineers accomplished theoretical work, finite element modeling, and experimental work for the in-house laboratory membrane mirror experiment.



The engineers used liquid crystal-based optically addressed spatial light modulators (OASLMs) for wavefront correction of up to 200 waves of optical aberrations. The directorate initiated investigations of beam projection and relay mirror applications using OASLM. The directorate established international, domestic, and academic technical relationships for this project. A new experiment, called the Fully Adaptable Telescope Experiment will exercise the fusion of the membrane mirror and the OASLM technology.

Background The directorate is investigating membrane mirrors for their lightweight, deployable, compact packaging and optical characteristics. The approach is to develop a new revolutionary telescope mirror technology using the stress-coated, net-shape, membrane mirror concept.

These membrane mirrors will form the large apertures in space-based optical systems. However, a membrane mirror coupled to a deployable, lightweight structure will not meet the precise tolerances needed by optical systems. Active control of the optical aberrations will be necessary to obtain the precise optical tolerances. The directorate plans to incorporate real-time holographic optical compensation methods.

ADT Research Team Achieves Outstanding Success

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Accomplishment The Directed Energy Directorate and Human Effectiveness Directorate Active Denial Technology (ADT) Research Team completed a United States Air Force Force Protection Battlelab initiative and demonstration in the field using an ADT technology demonstration system. These field tests consisted of a demonstration of power density at range, and researchers greatly exceeded all the exit criteria.

The ADT Research Team then conducted a series of human effects experiments in field tests at tactically significant ranges and spot sizes. Researchers exposed 82 human test subject volunteers four times each to the millimeter-wave electromagnetic energy beam, and observed and documented the resulting repel effects. The ADT Research Team transitioned these basic research results into real hardware systems for potential use by the warfighter.

Background The ADT Research Team recently completed a nine-month field test and demonstration of their non-lethal weapons technology. ADT is a breakthrough, non-lethal technology that uses millimeter-wave electromagnetic energy to stop, deter, and turn back an advancing adversary from relatively long range. Researchers expect ADT to save countless lives by providing a way to stop individuals without causing injury before a deadly confrontation develops.

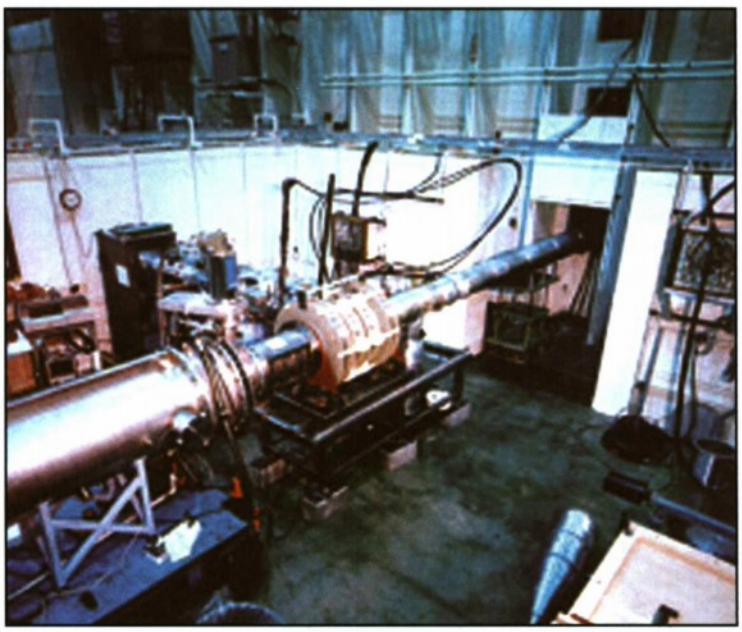
The two directorates and the Department of Defense's Joint Non-Lethal Weapons Directorate developed this technology in response to needs for field commanders to have options short of the use of deadly force. Peacekeepers can use non-lethal technologies for protection of defense resources, peacekeeping, humanitarian missions, and other situations in which the use of lethal force is less than desirable.

High-Power Microwave Source Solves Long-Standing Efficiency Dilemma

Payoff Directed Energy Directorate researchers investigated the Relativistic Klystron Oscillator (RKO) as a potential high-power microwave (HPM) source for a number of years. The source currently operates at gigawatt power levels and has high efficiency (>30%). One particularly intriguing feature of the RKO's efficiency, however, eluded explanation over the years.

A number of groups (Mission Research Corporation, The University of Michigan, and The University of California) using two-dimensional simulation, consistently found that the source should be operating at lower power levels than observed in the experimental testing of the device. The directorate used their in-house three-dimensional (3-D) parallel particle-in-cell code, called the Improved Concurrent Electromagnetic Particle-In-Cell (ICEPIC), to model the device in the most comprehensive way possible. This revealed the source of the discrepancy and paved the way for full deployment of this powerful source of HPM radiation.

Accomplishment The key feature of the experiment is that the direct current (DC) in the device slowly increases over time when modulated into alternating current (AC) by the radio frequency (RF) cavities. Researchers included this ramping current in ICEPIC simulations. The parallel nature of ICEPIC allows researchers to perform long simulations in full 3-D that mimic the pulsed power drive of the experimental system.



The combined effect of the 3-D structure and the ramping current has shown a new mechanism that enhances the efficiency of extracting RF from the modulated beam. The ramping DC current envelope on a modulated AC current induces a time-varying inductive voltage on the extractor gap. This effect increases the amount of HPM produced. With these effects included, the ICEPIC simulations compare favorably with experimental observations. These new simulations explain, for the first time, the enhanced microwave production seen in the RKO.

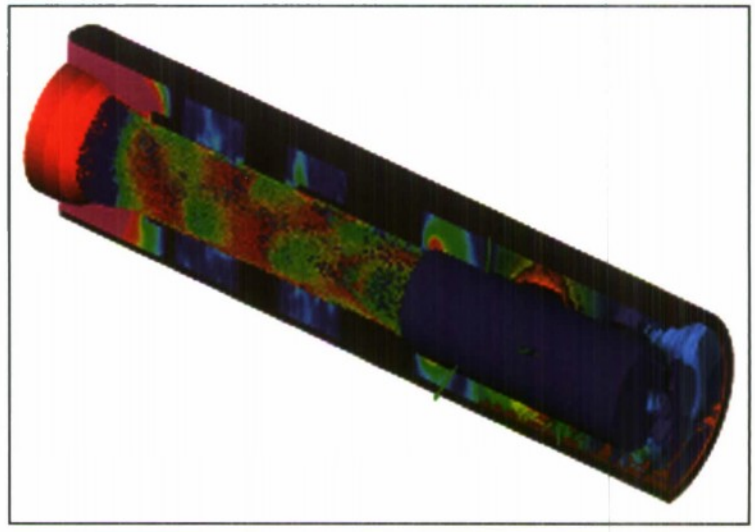
Background Researchers recognize HPM radiation as an effective means of directing energy in military, industrial, and scientific applications. Among the powerful sources currently under development, the RKO stands apart in terms of efficiency and robustness. The new inductive mechanism allows the possibility of exceeding the theoretical maximum efficiencies for relativistic klystrons. The higher efficiency reduces system constraints, leading to smaller pulsed power drivers. The resulting HPM system can therefore be more compact while retaining the high power needed to meet warfighter needs.

Improved Concurrent Electromagnetic Particle-in-Cell Models

Payoff The Directed Energy Directorate is developing a particle-in-cell (PIC) code, known as Improved Concurrent Electromagnetic Particle-In-Cell (ICEPIC), that models plasmas kinetically by numerically solving Maxwell's equations coupled with the Lorentz Force Law for charged particles. ICEPIC simulates collisionless plasma physics phenomena using a Cartesian or cylindrical grid in two or three dimensions (3-D).

Directorate researchers specifically designed ICEPIC for parallel high-performance computing resources by including several novel features such as automated partitioning, dynamic load balancing, and an advanced parallel PIC algorithm. ICEPIC adds a high degree of flexibility and power to the researcher's tools for high-power microwave (HPM) source simulation.

Accomplishment Directorate researchers used ICEPIC to perform the first end-to-end 3-D simulation of the Magnetically Insulated Line Oscillator (MILO) with a Vlasov antenna as well as the first end-to-end 3-D simulations of the Relativistic Klystron Oscillator (RKO) (as shown in the photo). This included detailed simulations of the three separate sections: cathode, oscillator circuit, and extractor.



Researchers also used ICEPIC to discover new critical physics for long-pulse HPM radiation in the MILO and a novel inductive energy extraction method in the RKO. In addition, they used ICEPIC to perform 3-D simulations of the Gyro-Backward Wave Oscillator and Radial Acceletron.

Background ICEPIC is written in "C" (a programming language like Pascal or Fortran) and uses the message passing interface standard to provide portability to a variety of systems. The Air Force Office of Scientific Research funds this software development effort. The directorate's High Power Microwave Division collaborates with NumerEx (a subcontractor of Science Applications International Corporation) in the development of ICEPIC. The Department of Defense High Performance Computing Modernization Office provides high-performance computing resources for the development and application of ICEPIC.

Multiblock Arbitrary Coordinate Hydromagnetics in Three Spatial Dimensions

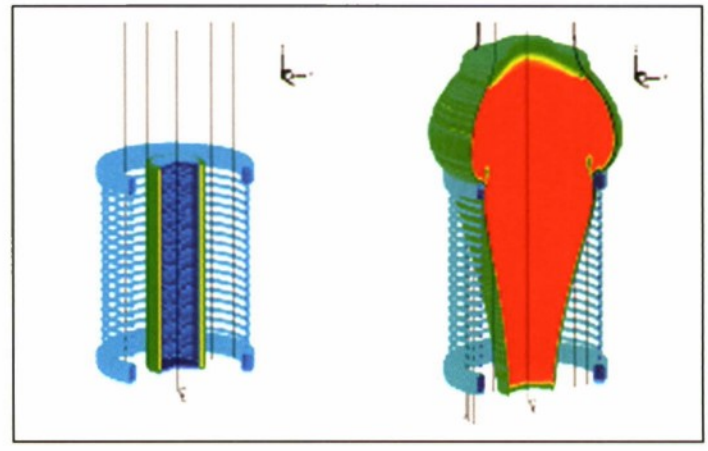
Payoff Multiblock Arbitrary Coordinate Hydromagnetics in three spatial dimensions (MACH3) is a three-dimensional (3-D) magnetohydrodynamics (MHD) code specifically designed to execute on parallel high-performance computing resources. MACH3 solves the continuum equations for conducting materials that are in the solid, liquid, gas, or plasma states. The software has advanced numerical methods for computing the time evolution of a magnetic field and its influence on the materials in the simulation.

Accomplishment The Directed Energy Directorate's High-Power Microwave Division is developing a general-purpose physics simulation code known as MACH3 to solve the unsteady, non-ideal MHD equations in complex geometries. Researchers used a structured, arbitrary coordinate 3-D grid for the 3-D version of this software based on the 2½-dimensional predecessor code, MACH2.

The MACH3 design allows researchers to divide and distribute extremely large computational domains into blocks, which are distributed across multiple computer processors and share common boundary information via the message passing interface standard. MACH3 can execute on the largest distributed memory multiple processor computing machines available.

Background During 2001, researchers used the 2½-dimensional predecessor software at over 40 government, university, and contractor institutions. The code demonstrated 3-D time-dependent simulations of an explosive magnetic flux compression generator (MCG). An MCG is a compact, pulsed power driver for numerous directed energy concepts.

In addition, researchers conducted 3-D time-dependent simulations of fast z-pinch experiments. Z-pinches generate powerful X-ray pulses for a variety of laboratory applications. The researchers also used the code for two-dimensional (2-D) time-dependent simulations of solid shell implosions. Such implosions can create extremely high pressures that researchers use to investigate the behavior of matter under extreme conditions.



Finally, researchers used MACH3 for 2-D and 3-D time-dependent simulations of high-speed flows in the presence of plasma. Such flows offer the potential to change the aerodynamics of hypersonic vehicles.

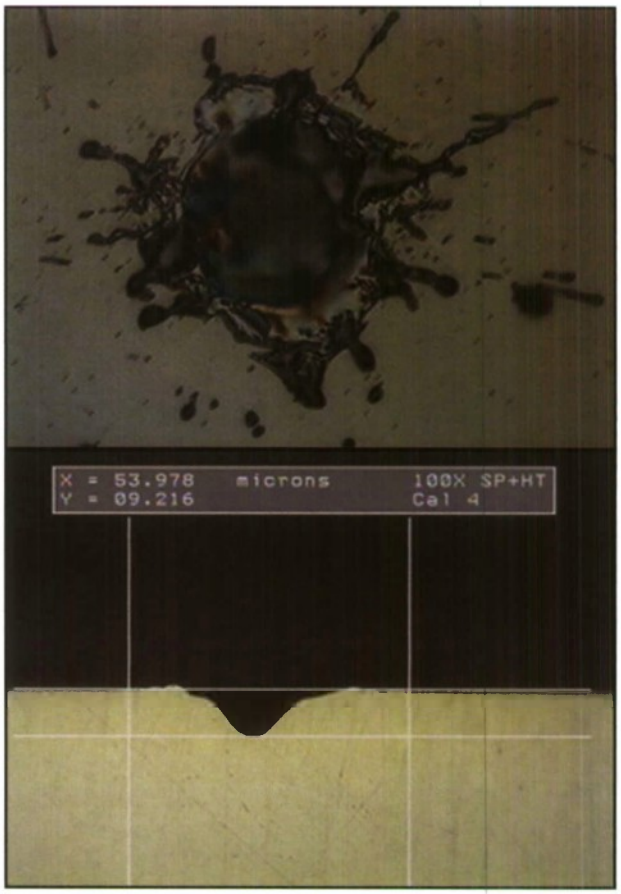
The fully 3-D code is under development with funding from the Department of Defense High-Performance Computing Modernization Office (HPCMO) and from the Air Force Office of Scientific Research. The directorate's High-Power Microwave Division's high-performance computing team consists of government researchers and on-site contractors from NumerEx (a subcontractor to Science Applications International Corporation) to assist in the development of MACH3. Furthermore, the HPCMO provides high-performance computing resources for the development and application of MACH3.

Laser Damage Studies on Focal Plane Arrays

Payoff Currently, the Directed Energy Directorate is developing a wide variety of military systems containing optical components and detector elements critical to their function. Concern about our ability to protect our assets from foreign, and sometimes our own, infrared (IR)-seeking missiles led to a need for a better understanding of the laser damage processes. Several mechanisms dependent on a variety of laser parameters produce laser damage. Wavelength, which determines if the material is transparent or absorptive to the radiation, and pulse duration, which determines the primary mechanism for the onset of damage, are among the variables investigated.

Accomplishment Directorate researchers recently performed a detailed study of laser damage to IR detector material and focal plane arrays (FPAs). Experimental results using a variable pulse format Nd:YAG (1.064 μm) laser to damage silicon, platinum silicon, and indium antimony FPAs elucidate damage as a function of energy.

Researchers also demonstrated the improved effectiveness of multiple pulses compared to single pulses on IR detectors. They discovered that the first pulse of a multiple pulse needs a less amount of the fluence compared to a single pulse laser. This discovery significantly impacts the requirements for lasers to defeat FPA-based IR seeker threats, ultimately resulting in smaller, lighter, and lower-cost countermeasure systems.

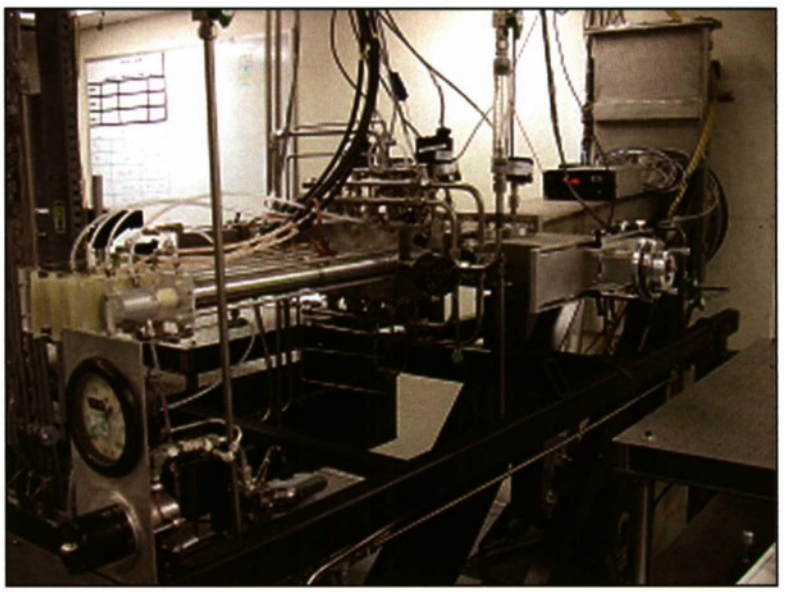


Background Determining the optimum damage mechanism to defeat FPA-based missiles is critical in establishing future IR countermeasure (IRCM) techniques and designing IRCM systems. The directorate is conducting extensive research to determine the optimum laser pulse format for causing catastrophic damage to FPAs. Directorate researchers conducted the study to determine functional dependence of IR detectors on pulsewidth and the effect of single- and multi-shot laser formats.

Directed Energy Directorate Invents New All Gas Laser

Payoff Researchers in the Directed Energy Directorate's High Power Gas and Chemical Laser Branch have worked on the All Gas-phase Iodine Laser (AGIL) project for the past five years. They believe this laser may have the potential for use in the Airborne Laser and Space-Based Laser programs.

Accomplishment The directorate designed AGIL to be more versatile than the Chemical Oxygen Iodine Laser (COIL) invented by the directorate in 1977. In particular, this new laser is potentially lighter in weight, operational in zero gravity environments and, because it is a purely gas phase reaction laser, will have a built-in heat rejection via its exhaust. The COIL was the first continuous wave electronic transition chemical laser. AGIL is the first continuous wave electronic transition chemical laser invented since then and, because of its gaseous form, Air Force officials believe it will have more utility.



Background The directorate's all gas-phase chemical laser, AGIL, creates its light by combining two specific gases—nitrogen chloride (NCl) and atomic iodine (I). AGIL's laser light results when electronically excited NCl transfers its energy to I and then releases the energy in the form of infrared light.

A series of reactions involving chlorine atoms and hydrogen azide generates the electronically excited NCl. Most chemical reactions do not produce electronically excited products; the reaction that produces the excited NCl is a rare exception.

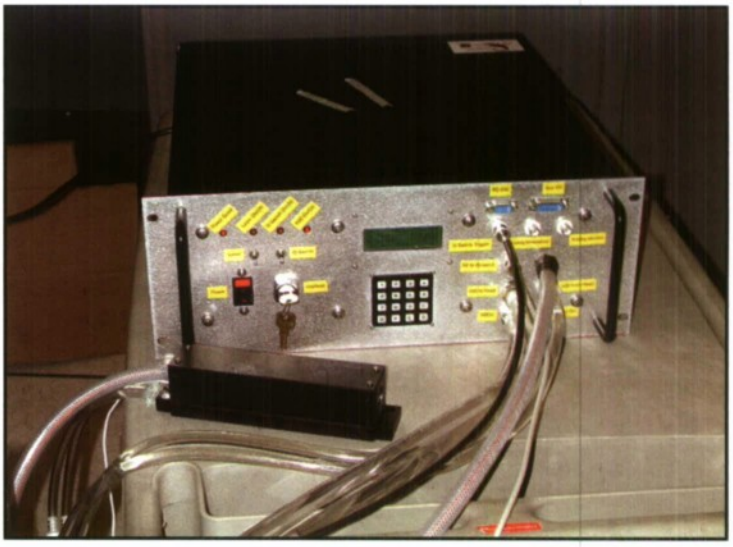
As the excited I atom relaxes back to its ground state, it produces a photon of light in the near-infrared region of the electromagnetic spectrum (1.3 microns). A relatively dilute mixture of NCl and I is capable of generating enough light to produce a low-power laser.

1.3-Micron Diode-Pumped Solid-State Laser System Used in Laser Radar Research

Payoff The Directed Energy Directorate's Solid State Laser Products Group inserted a 1.3-micron diode-pumped solid-state laser system into a Munitions Directorate ladar system. Munitions Directorate researchers will use this laser to test receiver performance and collect metrology data to determine optimal wavelengths for multi-wavelength operation. Multi-wavelength ladar is an active (illuminator) remote-sensing technique that will enable much greater ability to discern objects since objects have different reflection properties at different wavelengths.

Accomplishment The directorate developed and built a 1.3-micron diode-pumped laser system as part of an Air Force Office of Scientific Research effort to explore multi-wavelength laser radar. Directorate researchers are currently developing a second laser, operating at ~2.0 microns, in conjunction with the 1.3-micron system. This will allow Munitions Directorate researchers to explore the potential of such a multi-wavelength system for Air Force use.

Background The laser is an end-pumped Nd:YVO4 laser that produces 1.1 watts average power at 1.342 microns with a beam quality of 1.2-1.3 at a Q-switching frequency of 20 KHz. The pump is a 15-watt Specification or Design Language 3460-P6 fiber-coupled diode array that directorate researchers packaged into a 19-inch rack mount box containing the associated electronics to digitally control the diode output power and temperature via keypad or RS-232 interface. The electronics include a diode current driver, an acoustic-optic Q-switch driver, thermo-electric cooler/controller, and a laser interlock system tied to the diode laser cooling.

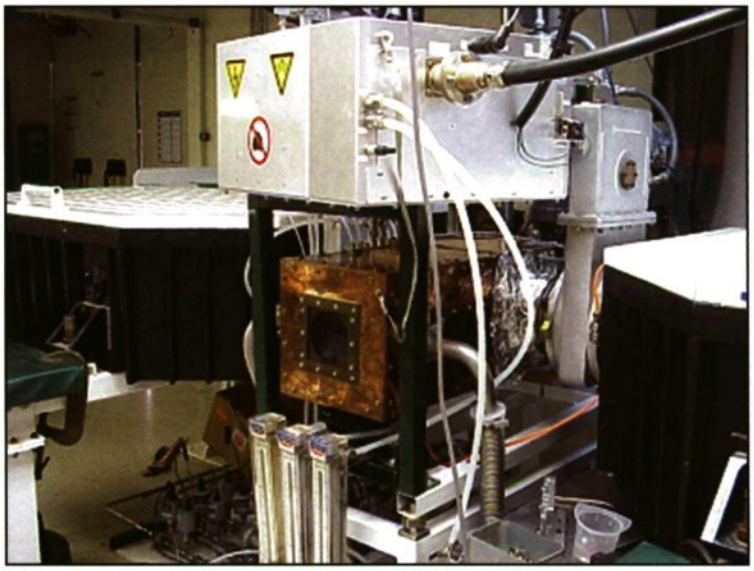


Supersonic Carbon Monoxide Overtone Laser

Payoff The Directed Energy Directorate's Supersonic Carbon Monoxide (CO) Overtone Laser program addresses the need for high-power 4-micron laser sources. The results of this effort will yield a scalable, frequency-agile device operating between 3.4-4.1 microns, which would make this system an attractive candidate for the Airborne Laser, Space-Based Laser, and Tactical High Energy Laser demonstration projects. Since the pump mechanism is electrical in nature, closed-cycle operation of the CO Overtone Laser would lend itself to a compact, flight-worthy design viable for military applications. This device would also be applicable for remote sensing.

Accomplishment This research yielded a maximum observed fundamental power (>.5 kW) utilizing a one-pass resonator. It also characterized fundamental band multi-line lasing transitions and demonstrated tunable, single-line lasing on fundamental band transitions.

More importantly, directorate researchers used this system to generate low-power overtone lasing at 2.7 microns. This is the first time researchers demonstrated lasing on CO overtone bands with a radio frequency (RF)-pumped supersonic system, and it was an important first step towards the long-term goal of CO laser output at 4 microns. In addition, the directorate's Chemical Laser Facility (CLF) established a working relationship with the Lebedev Physics Institute in Moscow, currently one of the world's leading authorities on CO lasers, to help accomplish further scientific breakthroughs with this technology.



Background The directorate is constantly researching the suitability of laser technology to meet Air Force warfighter requirements. Recent developments with CO lasers show significant potential for their applicability for airborne platforms. The build-up and testing of a supersonic RF-excited CO laser system has been ongoing at the directorate's CLF since 1999.

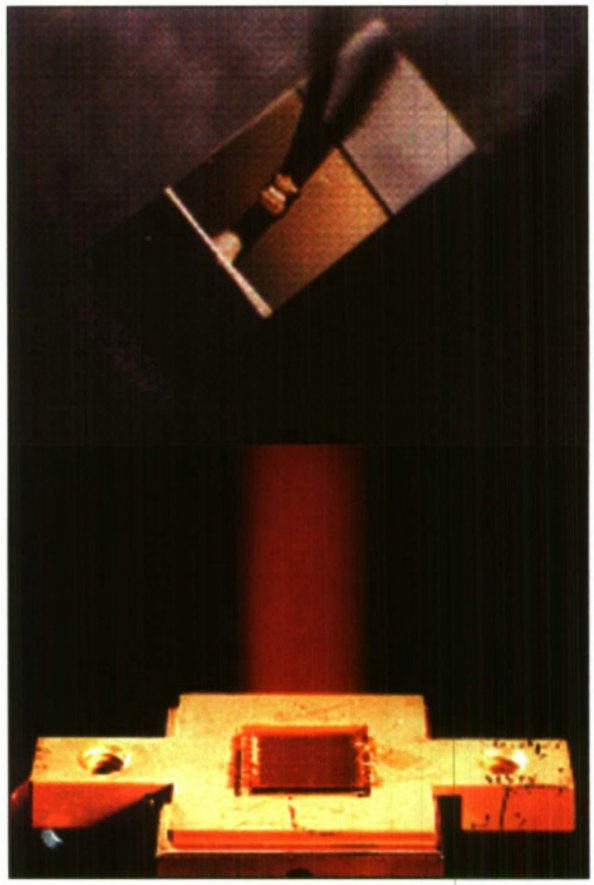
Low-Cost Diode Laser-Based Sensors Developed for Environmental Monitoring

Payoff Through a Small Business Innovation Research (SBIR) Phase I effort, Southwest Sciences showed that near-infrared diode lasers are useful for the detection of trace gases by optical absorption. As a result of this effort, Southwest Sciences sold diode laser-based instrumentation for the measurement of combustion gases, including several toxic gases, in tank fires.

Researchers use this instrumentation to characterize the performance of several fire suppressants and to measure concentrations and time evolution of toxic gases in tank crew compartments. Commercially, Southwest Sciences and an instrument manufacturer are jointly developing instrumentation for monitoring and process control in the semiconductor industry. The market forecast for this application alone is several hundred instruments per year.

Accomplishment The Directed Energy Directorate requires the ability to detect trace amounts of moisture to improve the manufacturing process for microelectronics and semiconductor laser devices. Southwest Sciences exploited the properties of diode lasers originally designed for applications, such as fiber optic communications and compact disk players, and developed instrumentation to detect ultratrace (sub parts per billion) levels of moisture in process gases.

The technology developed by Southwest Sciences has many potential applications for both the military and commercial sectors. The military can use this technology to monitor toxic gases on the battlefield and hazardous gases in rocket launch areas, and provide on-line diagnostics and control of advanced jet engines. Some promising commercial applications include monitoring and control of chemical processes, monitoring pollutant gas emissions, and measuring trace impurities in gas processes.



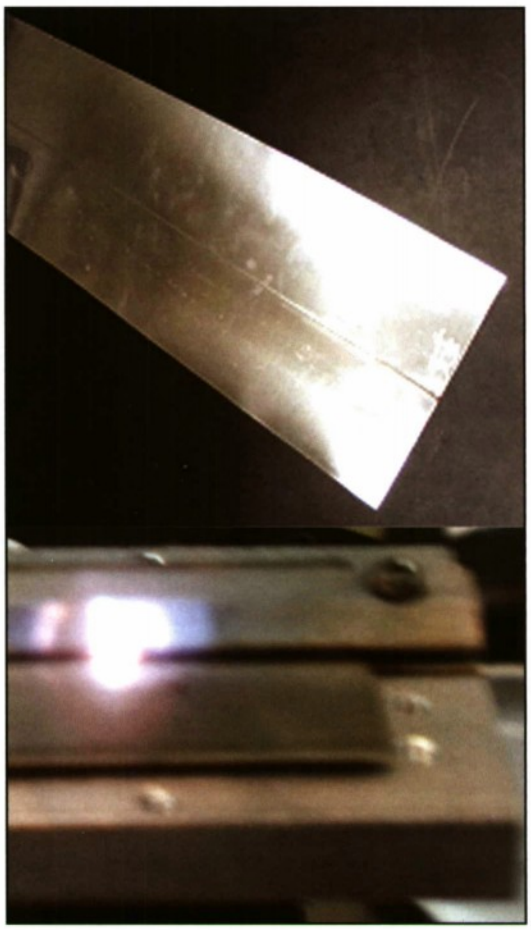
Background In order to improve the yield of manufacturing processes and the efficiency of semiconductor laser devices, manufacturers must closely monitor these processes to control the amount of moisture present. Many gases have characteristic absorption bands that overlap the operating wavelengths of these lasers and, in many cases, it is possible to provide highly selective and sensitive measurements of trace concentration of these gases.

In Phase II of this SBIR, Southwest Science focused on the development of a low-cost diode laser gas sensor that would be marketable for widespread commercial use. They developed a trace moisture sensor using a vertical cavity surface-emitting laser with excellent optical and spectroscopic sensitivities.

Advances in Laser Welding

Payoff By assisting Metal Tech Industries in microprocessing thin sheet metal, the Directed Energy Directorate is enabling the manufacture of many exciting new products. The first commercial application allows the manufacture of large gasket material, which fills a significant need for the petroleum, marine, locomotive, and chemical industries. These industries needed larger materials beyond the 1.0 x 1.0-meter size for some time.

These industries also have several applications requiring gaskets up to 1.5 x 1.5 meters. Lack of this product required the use of multipiece flanges. These flanges, which leak, caused many types of quality and environmental problems in manufacturing both military and civilian products. Manufacturers can use the technology arising from this effort to manufacture new products. The gasket marketplace already placed large gasket orders with Metal Tech.



Accomplishment This project addressed several advanced photonic technologies and their ability to provide exacting beam qualities. This project provided important insight into those abilities.

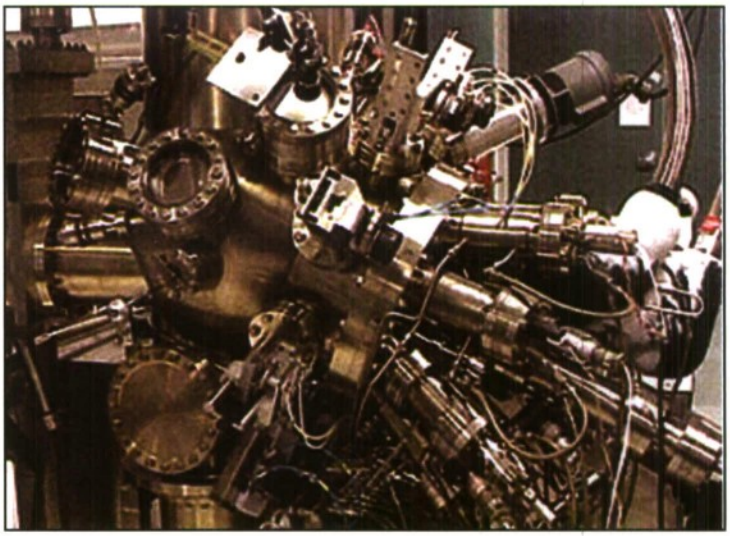
Metal Tech Industries, in partnership with the University of Central Florida, conducted many successful experiments for microwelding sheet metals with a laser beam in the Laser-Aided Manufacturing, Materials and Microprocessing Laboratory at the School of Optics/Center for Research and Education in Optics and Lasers. This research group, headed by Dr. Aravinda Kar, found that the optical-thermal phenomena in laser welding of sheet metals are different from those observed in thick metal welding. This finding will play an important role in manufacturing technologies for years to come.

Background The directorate and Metal Tech Industries jointly pursued improvements in the abilities of lasers to perform microwelding of sheet metals. This effort has many potential benefits for the military and will pave the way for Metal Tech Industries to become a leader in the field of metallic gasket manufacture.

Mid-IR Semiconductor Lasers with Record Power and Brightness

Payoff The much-improved lateral beam quality of the mid-infrared (IR) semiconductor lasers will enable novel beam-combining schemes that can improve brightness from a small array of semiconductor devices. Consequently, this new generation of lasers results in a substantial reduction of risk in developing compact, efficient sources for numerous applications.

Accomplishment The Directed Energy Directorate Mid-IR Semiconductor Research group's in-house research and development produced 4-micron semiconductor lasers. These lasers have many characteristics that make them attractive for applications requiring compact systems.



The directorate demonstrated lasers with record output powers based on advances in type-II quantum well epitaxial growth technology coupled with an improved understanding of the opto-electronic properties of nanometer-scale antimonide thin films. In addition, optimized cavity designs that limit the tendency for filamentation led to a reduction of the slow- and fast-axis divergence, approaching diffraction-limited output.

The increased power, concentrated in a less divergent beam, results in unprecedented brightness for semiconductor lasers operating at this wavelength. This accomplishment strongly benefited from a fruitful interaction with the University of New Mexico's Center for High Technology Materials. The directorate and the University of New Mexico share the epitaxial growth facility.

Background Scientists can engineer semiconductor lasers to have substantial wavelength agility, with power outputs that can be modulated at high rates, and as semiconductor products that can be mass-manufactured. Since these lasers are extremely small and highly rugged, they are oftentimes ideal for low weight and moderate power applications. Despite enabling the telecom revolution at the 0.8-1.5 micron wavelength range, semiconductor laser development for emission in the mid-IR (3-5 microns) wavelength range is not yet mature.

The directorate pursued contractual development of lasers emitting in the mid-IR wavelength range for numerous applications. The principal achievement of this program was the development of optically pumped 4-micron lasers.

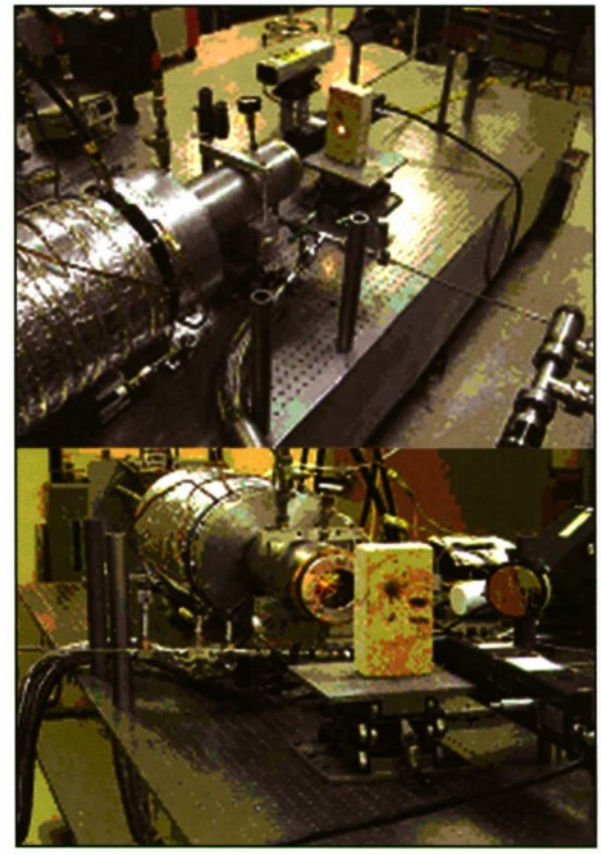
Radial Non-Ceramic High-Power Waveguide Laser for Multiple Uses

Payoff The unique radial waveguide laser system is low cost, has a high power-per-unit weight, and is easily scalable to higher powers. The power-per-weight is much higher than any comparable solid-state laser. In addition, by using other gaseous lasing species, high power at 3.5-4.6 microns and high brightness lasing at 1-2 microns are possible.

The Directed Energy Directorate is pursuing this technology for use in aircraft self-defense, munition removal, and illuminators due to its low cost, good beam quality, and long-term operation. The emphasis for the future is to scale these systems to much higher power, demonstrate good beam quality and efficiencies greater than 10%, and investigate lasing species at attractive wavelengths in the near- and mid-infrared region.

Accomplishment During the last year, the directorate developed a non-ceramic, radially configured, radio frequency (RF) waveguide laser that demonstrated high power with multi-beamlets lasing at 10.6 microns. The newly designed laser system is a non-ceramic system with excellent operation, no vacuum degradation, high power, reasonably good beam quality, and easy assembly.

The most significant advances include (1) a design incorporating all non-ceramic and easily assembled material seals, (2) efficient low-cost manufacturability with a minimum of vacuum and water seals including both water cooling of electrodes and RF feedthroughs, (3) easy resonant cavity tuning for maximum RF energy storage and excitation of multiple waveguide beamlets, (4) reliable laser operation without vacuum failure from any thermally or high-power RF-induced expansions, (5) reliable mirror systems incorporating close mirror-electrode spacing (< 2 millimeters) without RF arcing, and (6) good extractable energy from each waveguide beamlet.



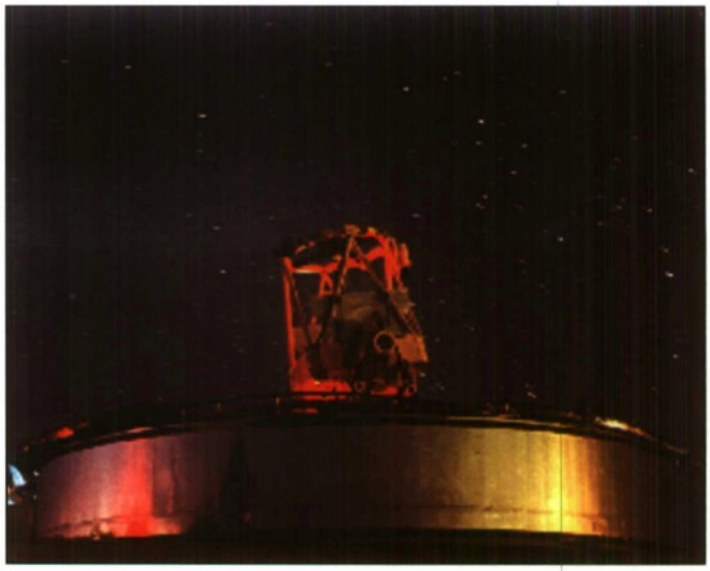
Background RF waveguide lasers are attractive as compact, lightweight systems often employed in machine processing. Unlike most electric discharge lasers (EDLs), these lasers depend upon diffusion for the thermal management of gaseous lasing medium similar to solid-state lasers.

This method eliminates the need for large mechanical pumps required for the convective cooling in high-power EDLs and chemical lasers. Directorate researchers demonstrated kilowatt power levels with carbon dioxide before using ceramic materials for the RF insulator. The sophisticated geometry necessary to create good beam quality at high powers is quite costly and often impossible to fabricate out of ceramics. A totally non-ceramic system offers the advantage of lower cost and more compact systems.

First Compensated Satellite Illumination from the SOR 3.5 m Telescope

Payoff This experiment represents a major advance in the beam control capabilities necessary for ground-based laser weapons. The Directed Energy Directorate's Starfire Optical Range (SOR) demonstrated effective integrated beam control on a weapons-class scale and made the first real measurements of the effectiveness of atmospheric compensation. Data from this experiment furnished the first characterization of the effects of anisoplanatism (point-ahead turbulence effects) in a satellite engagement.

Accomplishment Directorate researchers used the SOR's 3.5 m telescope to propagate a compensated laser beam to a retroreflector-equipped satellite. They measured the reflected signal at the SOR 1.0 m beam director. Researchers then used the telescope's 941-channel adaptive optics system to compensate the outgoing laser beam for the effects of atmospheric turbulence, producing measured increases of factors of 5-10 over uncompensated beams.



Researchers used a 20 watt (W) neodymium doped yttrium aluminum garnet laser, reduced to 1-3 W to avoid saturating the receiving sensor. They first performed compensated laser propagation from the SOR's 1.5 m telescope in 1991.

This experiment marks the first propagation of a compensated laser beam from a weapons-class aperture and the first-ever measurement of compensated versus uncompensated laser energy on a satellite target. Directorate researchers repeated the experiment, furnishing a valuable collection of real-world compensated laser propagation data for validation of theory, models, and future system design.

Background The directorate's SOR is an advanced optical research site, located at Kirtland AFB, New Mexico, to develop advanced optical wavefront control technologies. Research focuses on field experiments in adaptive optics to compensate for the effects of atmospheric turbulence upon lasers and imagery. This technology is key for both real-time space imaging and a variety of laser weapons applications.

Equipment includes three major optical mounts: a 1.0 m beam director, a 1.5 m telescope, and a 3.5 m telescope, all capable of tracking low-earth orbit satellites. The 3.5 m telescope, equipped with a 941-channel adaptive optics system, is currently the largest and highest performance atmospheric compensation system in the world. The 3.5 m telescope/adaptive optics combination is highly successful, producing images of stars and satellites with resolutions approximately 65 times better than normal images and very near the theoretical limit of the telescope.

Development of a Reference Dose for Ammonium Perchlorate

Payoff Appropriate toxicological studies are critical to the establishment of scientifically based standards for remediation of perchlorate, a chemical that prevents iodine uptake of the thyroid gland. This research will lead to a formal peer-reviewed process to establish regulatory standards for perchlorate. Currently, recommended action levels are low, provisional, and based on limited analytical detection capability and incomplete data. This standard will protect human health without undue restrictions and could reduce clean-up costs substantially.

Accomplishment The Interagency Perchlorate Steering Committee (IPSC) is a partnership between state and Environmental Protection Agency (EPA) regulators, industry, and the Air Force. The IPSC serves as a single toxicology point of contact for customers, regulators, and media on multiple, independently completed toxicology research efforts. This committee ensures the maximum efficiency of resources and optimal solutions in a timely manner.

The participation of the Human Effectiveness Directorate's Operational Toxicology Branch in the IPSC ensures that research conducted provides risk managers (Air Force/insulation and logistics, and base environmental managers) with the necessary data to make health-based decisions. Final regulatory decisions affect Air Force personnel, the public, and the disposition of Air Force property and contracts.

The directorate's in-house toxicology research and collaborations generate critical toxicity information that fills substantial data gaps concerning the effect of perchlorate on the thyroid gland. The directorate's research led to a draft assessment document in 14 months versus the traditional 10-12 years.

Background The United States Government specifies the use of ammonium perchlorate (AP) powder as an oxidizer in most solid rocket motors. AP's high solubility in water results in a long-lived perchlorate ion that competes with iodine, resulting in an iodine-deficient thyroid or goiter.

EPA regulators discovered AP-contaminated drinking water sources in California and Nevada and in groundwater in Utah, Arizona, Texas, Maryland, Arkansas, Florida, West Virginia, and at Holoman Air Force Base in New Mexico. The IPSC partnership is providing the best decisions to minimize duplication of effort while informing the public of perchlorate-related events. The directorate and industry are addressing the significant data gaps identified by the first draft assessment.

AFRL Develops "FANTASTIC" Approach to Air Traffic Control Restrictions

Payoff The Information Directorate is developing a cost-effective solution for upgrading United States Air Force tactical fighter and civilian platforms in an effort to meet new and evolving air traffic control restrictions imposed by the Federal Aviation Administration and international governing bodies. The program is called Future Air Navigation and Traffic Avoidance Solution Through Integrated Communications, Navigation, Surveillance (CNS) (FANTASTIC).

Accomplishment FANTASTIC targets Air Combat Command tactical aircraft, such as the F-15E and F-16CJ, whose size/weight/power restrictions preclude the use of commercial equipment to meet the new and evolving air traffic control restrictions. The directorate's Information Grid Division, Platform Connectivity Branch, working with Rockwell-Collins scientists and engineers, found that non-compliance with Air Traffic Control requirements impacts both cost and mission. Restrictions could range from non-preferred routes and operating altitudes to precluding certain missions altogether.

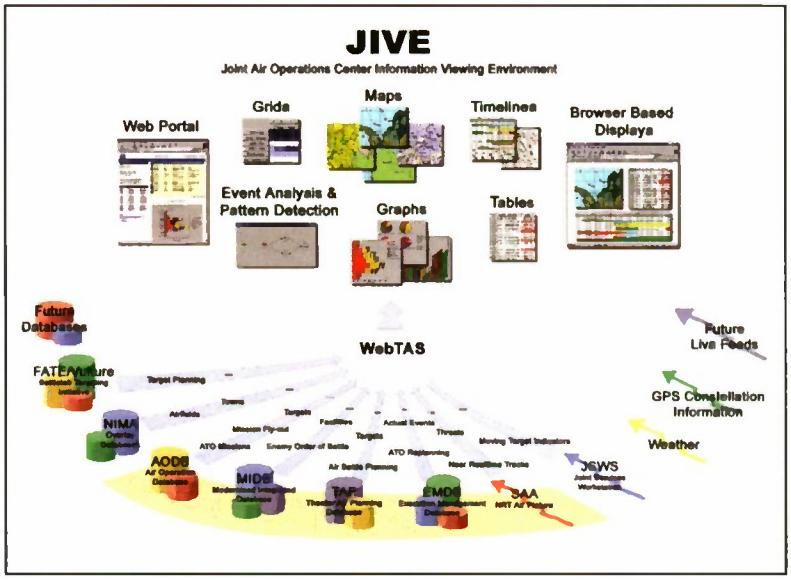
Directorate engineers recently demonstrated FANTASTIC's fully compliant hardware/software system that weds a unique blend of a state-of-the-art receiver/processor with Future Air Navigation System (FANS)-certified software, currently employed in the air transport fleet. The FANTASTIC program-developed receiver/exciter, called the Miniature Modular Digital Radio, employs commercial off-the-shelf components, patented software, and a direct conversion receiver architecture, meeting all global air traffic management (GATM) requirements in an incomparable combination of small size and low cost. Engineers combined a Fast In-Phase/Quadrature processor to provide a baseline for a radio system in two standard electronic module, type E modules. Commercial software from Rockwell-Collins' Air Transport Division provides significant cost containment.

Background Rockwell-Collins transitioned interim products from the FANTASTIC program to military and civilian applications. They loaned the receiver/processor pair to the military's Airborne Communications Node program for the Phase I demo with planned transition to the F-22, Joint Strike Fighter, and Comanche, saving hundreds of millions of dollars. They also transitioned very high frequency (VHF) data link and communications management software to the ARC-210 radio. The general aviation market business and personal aircraft are the primary civilian targets of the FANTASTIC program. Products transitioned to the commercial sector include VHF data link software insertion into the general aviation and air transport VHF radios. The Office of the Secretary of Defense (Science and Technology) recently recognized the FANTASTIC program as a recipient of the first annual Dual Use Award.

JAOC Information Viewing Environment

Payoff Web-enabled Temporal Analysis System (WebTAS) software provides the capability to easily access disparate data sources, including real-time feeds, and visualize the data together, overlaid on a map, timeline, graph, or table as defined by the user. This software reduces the time to access and visualize data, resulting in reduced man-hours for data aggregation, and decreases critical decision-making time by the Joint Aerospace Operations Center (JAOC) staff.

Accomplishment The Information Directorate, in partnership with the United States Air Force Command and Control Battlelab (C2 Battlelab), applied the WebTAS for data access and visualization of JAOC data sources. The WebTAS software is a government off-the-shelf product developed over the last three years by Intelligent Software Solutions (ISS) under contract to the directorate.



For prototype assessment, ISS engineers sourced data from the Theater Battle Management Core System to include the Air Operations Database, Modernized Intelligence Database, and Situation Awareness and Assessment. ISS engineers also sourced data from the Joint Services Workstation, Air Defense System Integrator, Tabular Formatted Airfield Data System, and Federal Assessment and Targeting Enhancement.

Directorate engineers accomplished an initial assessment at Exercise Roving Sands 01 for the 8th Air Force. The directorate's engineers installed the JAOC Information Viewing Environment (JIVE) in the Combined Air Operations Center-Experimental at Langley Air Force Base, Virginia for further spiral development.

Background No single viewing environment exists for all the data sources in a JAOC. JAOC staff members can only see certain data sources on specialized viewing equipment developed solely for a specified data source. A multitude of different database types also makes simultaneous access extremely difficult.

The C2 Battlelab identified, from warfighter input, accessible Aerospace Operations Center data sources and visualized them onto a common viewing environment. While other agencies and the United States Southern Command used WebTAS, directorate engineers applied JIVE technology for the first time to the JAOC.

Advanced Electronic Insulating Materials Offer Higher Temperature Capabilities for Next Generation Systems

Payoff Low dielectric constant polymers will provide the Air Force with significantly improved insulating materials for a diverse range of electronics applications directly benefiting US national security. These new polymer materials are tough, can handle high temperatures during manufacturing, have good adhesion to different types of surfaces, and are essential for fast signal processing as well as high density and low noise electronics. These combined qualities allow for the production of lighter weight, highly efficient signal processing systems and offer tremendous potential for important commercial applications in the private sector.

Accomplishment Scientists at the Materials and Manufacturing Directorate's Nonmetallic Materials Division developed a new family of materials that will dramatically improve the high-speed integrated electronic circuitry supporting important military defense systems. These high-performance insulating materials, low dielectric constant polymers can handle the ultra fast processing speeds and high temperatures the Air Force will need to operate and sustain next generation air and space systems. Applications include high-speed computers, space-based radar, satellite communications, high-resolution imaging, and miniaturized electronics packages.

Background Next generation air and space systems require even smaller microelectronic packaging. This is driving the requirement for new insulating materials with higher temperature operational capability and ease of high-temperature fabrication. Directorate researchers discovered a family of polymer materials that meets these stringent objectives.

Scientifically referred to as flexible, aromatic benzoxazole polymers (containing perfluoroisopropyl units), and more commonly known as low dielectric constant polymers, these advanced materials are crucial because they enable higher circuit density. The high-element density electronic chips currently in use in Air Force warfighting support systems are rapidly approaching their optimal performance levels. Making them smaller could lead to interconnect delays and reductions in the speed of the circuitry.

The directorate's research team demonstrated that low dielectric constant polymers exhibit extremely low levels of water absorption, which is important for integrated circuit processing. They also demonstrated that the thermal expansion, energy loss, and directional uniformity, all critical factors in producing a highly efficient insulation material, are well within the acceptable limits for integrated circuit applications. These combined characteristics make the behavior of the new insulating materials extremely predictable, while allowing higher temperature processing and needed assembly capabilities.

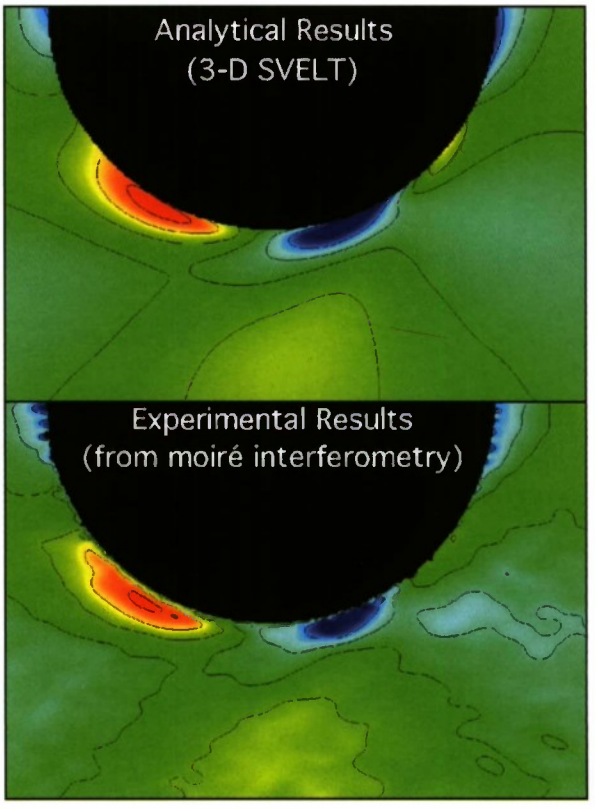
Measurements on films of the materials in the new benzoxazole polymer family resulted in typical dielectric values of 2.1 to 2.5 at one megahertz—values that are significantly lower than the state-of-the-art. This achievement is very important to the electronics community because smaller size electronic devices will soon require insulators with these newly achieved low dielectric values.

Advances in Bolted Composite Joint Strength Prediction Improve Structural Integrity of Military and Commercial Aircraft

Payoff A Materials and Manufacturing Directorate's cooperative effort yielded significant breakthroughs in mechanical modeling that provide greater insight into the strength of bolted composite structures, while reducing cost and risk on future programs. This effort also demonstrated the formation of unique partnerships between government and industry to achieve solutions to complex problems.

Accomplishment Materials research scientists at Wright-Patterson AFB, Ohio, in cooperation with industry, continue to make dramatic advancements in mechanical modeling to predict the strength of bolted composite joints that are critical to safe and cost-effective flight operations. The ability to predict the strength and evolution of composite materials damage, such as cracking and delamination particularly at microscopic levels, profoundly impacts the design of future composite structures, while trimming millions of dollars off life-cycle costs.

Background In the past, industry used several different methods to model the strength of bolted composite joints including two-dimensional, semi-empirical models that assumed a fixed contact zone between the bolt and the composite material. Industry methods predicted strengths that varied considerably from statistically measured joint test configurations. Due to the difficulty in conducting combined loading tests, comparing test results to predictions of simulated structures subjected to multiaxial loading and shear was not possible.



Directorate researchers developed a new, advanced method based on accurate three-dimensional stress analysis called Spline Variational Elastic Laminate Technology (SVELT). In-house efforts experimentally validated the new analysis method, focusing on initial ply failure and surface strain behavior around the hole. Qualitative agreement between SVELT predictions and actual initial failure locations, and the excellent quantitative experimental and analytical strain behavior indicated that SVELT was accurately predicting ply-level behavior. Further experimental investigations verified the accuracy of ply-level predictions of stress and strain and justified additional investigation.

SVELT refinements and modifications include the provision of an elastically deformable bolt. This technology can also examine where a pure interference fit exists between the bolt and the hole. The Air Force and industrial participants signed a formal partnership ensuring the availability of industrial participation to help guide future SVELT development efforts.

Versatile Transparency Material Offers Superior Protection While Saving Millions of Dollars

Payoff Polycrystalline aluminum oxynitride, or ALON™, satisfies a diverse range of technological interests throughout the Department of Defense (DoD) and other federal agencies due to its extensive versatility. It offers performance and scaling not otherwise possible for large, strong, lightweight, infrared (IR) transparencies and transparent armor applications that are affordable. Military applications include forward-looking IR windows and domes, such as missile domes and towed underwater sensors, and transparent armor including windows for motor vehicles, riot shields, and protective headgear for bomb disposal operations. Commercial uses for ALON include supermarket scanner windows, currently being field tested; watch crystals; and scratchproof lenses.

Accomplishment Research engineers at the Materials and Manufacturing Directorate, working with Raytheon Electronic Systems, identified a tough, lightweight, transparent material that could substantially reduce the cost of windows on military reconnaissance aircraft. Directorate engineers are scaling this new material, ALON, into 20in. long by 14 in. wide blanks to evaluate forming techniques and optimize fabrication processes, in order to produce a window for flight testing. The successful development and transition of ALON could reduce the life-cycle cost of reconnaissance aircraft windows by as much as $25 million, while providing greater protection for flight and ground vehicle crews.

Background ALON is an extremely tough, lightweight, transparent ceramic material offering outstanding potential for both military and commercial applications. ALON offers significant advantages over conventional materials currently used to make windows for reconnaissance aircraft, missile domes, protection shields and lenses, and other important products.

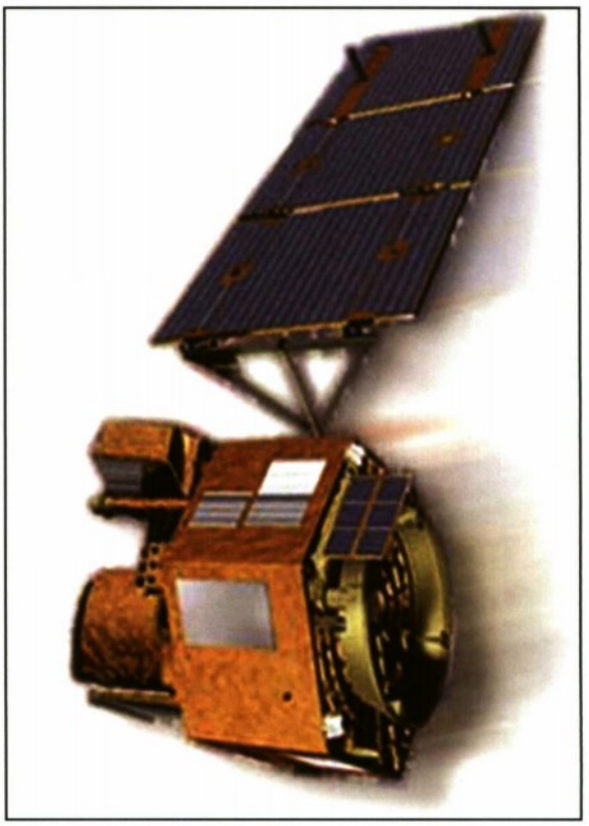
ALON is a very durable, optical material with a high degree of transparency from the ultraviolet through the mid-IR wavelengths. A potential market exists for its use in commercial supermarket scanners, which are manufactured in quantities of tens of thousands of units per year. ALON is equivalent to sapphire in terms of optical quality, low density, high strength, and high durability; however, ALONTM is an isotropic ceramic, making it scaleable by conventional powder processing methods.

ALON demonstrates outstanding ballistic impact resistance, making it an excellent candidate for motor vehicle windows designed to safeguard occupants. The new material is IR transparent; whereas glass, polycarbonate, and other conventional materials are not. Directorate engineers identified tens of thousands of window panels throughout the DoD as potential applications for ALON technology.

Government and Industry Team Creates Lightweight, Highly Conductive Space Radiator Panel

Payoff Carbon-carbon has the widest range of tailorable thermal conductivity and stiffness among the elements. It has a low density and, in some circumstances, is two to three times lighter in weight than aluminum. High conductivity carbon-carbon facesheets enable radiator panels to dissipate more heat, thereby reducing, and possibly eliminating, the number of required heat pipes. Based on the success of in-flight tests, the panel may change the way spacecraft builders and integrators view carbon-carbon.

Accomplishment A partnership between government and industry yielded a revolutionary carbon-carbon space radiator panel that could increase the service life of satellites, while reducing the cost of putting them in orbit. Partners included AFRL's Materials and Manufacturing and Space Vehicles Directorates, the Navy, the National Aeronautics and Space Administration (NASA), and Lockheed Martin. NASA launched the earth observing satellite, installed with the radiator panel from Vandenberg AFB, California. The satellite is the first of three new millennium program earth-orbiting missions that demonstrates new instruments and spacecraft systems.



Background Researchers know future spacecraft will require smaller and more closely packed electronic components and lightweight radiator panels that conduct more thermal heat. In response to future requirements, researchers from the Materials and Manufacturing Directorate's Nonmetallic Materials Division and NASA created the carbon-carbon space radiator partnership. Satellites in orbit carry electronic components that generate heat while performing their jobs and absorbing radiation. Radiator panels, which are a structural element of the satellite, prevent damage to heat-sensitive components by conducting and radiating heat away from them.

In the past, researchers used aluminum in satellite radiator panels because of its conductivity, and structural and physical properties. In order for aluminum panels to work, they must be thicker near high heat load zones. However, lighter weight and superior performing material alternatives exist such as carbon-carbon.

Emerging Technology Saves Time and Money Transporting Users into the "World of Oz"

Payoff An object management system called Object Czar® (referred to as Oz) reduced project management task support time by 30% during validation. Used in a Virtual Manufacturing Enterprise (VME), Oz reduces parts acquisition costs by up to 70%, decreases logistics response times by more than 50%, and increases the supplier chain to more than 170 companies. This increases user flexibility; provides timely performance, visibility and global data accessibility; and reduces the learning curve as well as application design, development, and implementation costs. Design of this tool allows it to operate in a Common Object Request Broker Architecture (CORBA), NT®, or Windows® environment with user-friendly Microsoft® products such as Excel, Word, and PowerPoint.

Accomplishment Under a contract with the Materials and Manufacturing Directorate, researchers at Knowledge Base Engineering (KBE), Inc. developed Oz. Oz has proven in a global environment that it can link data spread across a wide range of computers, networks, databases, and computer-based application tools. Air Force engineers and project managers using Oz find that it shortens the cycle time for the procurement of new technology and enhances program stability.

Background Developed under an Air Force-sponsored Small Business Technology Transfer contract, Oz is a secure environment that provides point-and-click capabilities to create and maintain end-user production applications. With Oz, project team members and administrative personnel can obtain different privileges and work in a secure environment.

The Oz-Integrated Program Management is a tool for engineers and scientists to manage work flow and projects. As various team members or contributors provide input, Oz automatically generates charts, reports, and graphs in both text and graphics. Oz provides immediate access to mission critical data, allows managers and project team members to maintain their shared data, automatically creates case files, and supports records managers.

Oz can incorporate Microsoft office capabilities automatically.
The manufacturer leverages the KBE-developed universal object-oriented scheme that has a similar structure to the Windows Explorer hierarchical version for Oz applications. Oz uses CORBA and Open Database Connectivity to communicate with local and remote databases such as Microsoft Access and SQL Server, Oracle®, and Borland® InterBase®. KBE provides an Oz multitiered distributed application server with a powerful application programming interface, both of which are state-of-the-art in the computer industry.

Team members used Oz to successfully integrate and manage a VME, a coalition that began with more than 100 small, high technology manufacturing organizations throughout the United States. Each small manufacturing operation performs a specialized role in the VME process in order to deliver a quality product at a reduced cost to the government.

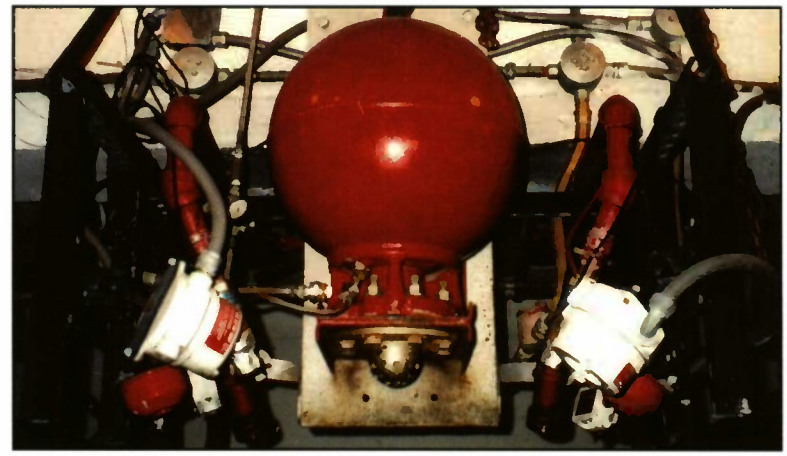
New Suppression System Extinguishes Fire Ignition in Milliseconds

Payoff Munitions workers will soon be able to conduct inherently dangerous tasks while protected by a fire suppression system that is both faster than and superior to previous technologies. This system enhances productivity and virtually eliminates current environmental contamination hazards caused by accidental system discharges. Engineers conducted first-time electromagnetic radiation measurements of pyrotechnic and propellant materials and provided this information to commercial high-speed optical detector manufacturers to further develop/improve their detectors.

Accomplishment Engineers at the Materials and Manufacturing Directorate's Fire Research Laboratory developed a fire protection device that responds to a propellant or pyrotechnic munitions fire in four to eight milliseconds. More than ten times faster than current Department of Defense standards, this Advanced Fire Protection Deluge System (AFPDS) will save lives, reduce injuries, and save millions of dollars in property damage at munitions manufacturing and surveillance facilities.

Background Hazardous, flammable, and explosive materials pose a significant risk in military plants that produce, maintain, and renovate munitions. The United States Army Operations Support Command and the private sector have suffered severe loss of life and property damage due to related incidents. Their facilities also encounter false alarms from the reaction of fire suppression systems' ultraviolet detectors to non-threatening catalysts in the area of detection.

At the request of the Army Defense Ammunition Logistics Activity, the directorate's Fire Research Group at Tyndall AFB, Florida, examined speed, effectiveness, and false alarm concerns with the Army's existing high-speed deluge fire protection systems. Directorate engineers developed and tested the AFPDS using an electronically integrated combination of commercially available high-speed, false alarm-immune optical fire detectors, a controller operating at less than a millisecond, and pressurized water expelled in small particles from high-rate discharge spheres.



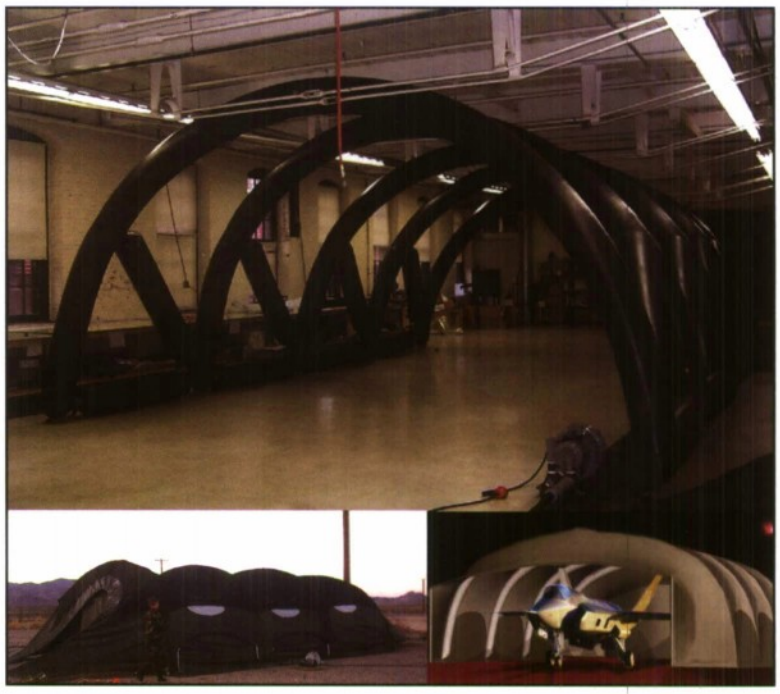
Although the system extinguished over 99% of more than 200 burns (test fires) in the stand-alone mode, the engineers provided pressurized water for a few additional seconds from standard nozzles. This test proved the system useable as a stand-alone suppression device or as a complement to existing systems without replacing the current deluge systems.

To date, the system has successfully detected and extinguished test fires from 17 pyrotechnic, high-explosive, and propellant materials. Each of the system's multi-spectrum detectors also performed superbly against a host of directorate-created false alarm sources similar to those found in plants and arsenals. In the remote chance of activation, the AFPDS expels only two to five gallons of water compared to current systems that use up to 15,000 gallons, virtually eliminating environmental runoff problems.

Inflatable Structures Can Reduce Logistics and Setup Time for Bare-Base Operations

Payoff Shelters made with inflatable air beam technology could greatly reduce the manpower required to set up deployable shelters, as the existing shelter requires eight people and the inflatable shelter requires five. Researchers expect to reduce deployment time by 75% and labor hours, required by deployed forces to construct shelters, by nearly 85%. Researchers anticipate the shelters to be 60% lighter and require only a single shipping container in lieu of three, which will allow twice as many shelters shipped per transport aircraft.

Accomplishment Researchers at the Materials and Manufacturing Directorate, in conjunction with the Army, are developing a new temporary aircraft shelter for deploying forces that is significantly lighter, faster to transport, and easier to construct. The inflatable structure will dramatically reduce deployment logistics including the amount of time, people, and aircraft required to set up bare-base operations.



Background One major concern for forces deploying to bare-base locations is constructing large shelters for use as aircraft hangars, maintenance facilities, and storage warehouses. Many of the current shelters use aluminum frame tent technology and take several civil engineers many hours to days to construct.

A six-year cooperative research and development effort between the directorate's Deployed Base Systems Branch at Tyndall AFB, Florida and the United States Army Soldier and Biological Chemical Command at Natick, Massachusetts, produced inflatable textile air beams to replace the heavier aluminum structural frame. These high-performance beams feature high strength under applied loads, high stiffness, low weight, and high overload to deflect weight or load without damage. Researchers expect air beam-supported shelters to protect aircraft against environmental effects and provide a controlled environment for maintenance, while reducing the amount of time and energy required to deploy, construct, and maintain a functional shelter.

During the summer of 2001, the branch evaluated two small-sized shelters at their facilities at Tyndall AFB. During fiscal years 2002 and 2003, researchers expect to choose a manufacturer, based on this testing, to design, build, demonstrate, and evaluate a shelter large enough to house an aircraft.

Follow-on efforts will incorporate smart skin for protection against toxic chemical effects, integrate next-generation power utilities, and accelerate the transition of all other bare-base shelter support equipment. In addition, the air beam technology manufacturers anticipate numerous technology spin-offs useful to the military services.

ORB_IT Software Allows Enterprise-Wide Computing

Payoff Object Request Broker (ORB), known as ORB_IT, provides seamless connectivity to distributed databases of many different kinds and may save about 95% of the cost and effort needed to convert legacy databases into modern databases. To facilitate transition of data, organizations will develop "software adoptions," which will require about 5% of the effort needed to obtain data from legacy data sources to ORB_IT and the network.

An organization does not need to "retire" all its legacy computing platforms and applications and buy new computing systems. In a large organization, such use of legacy platforms and applications can result in savings of millions of dollars, which otherwise would be spent on purchasing newer computing platforms and rewriting the legacy applications to run on modern systems.

Accomplishment A Small Business Innovation Research Phase II contract effort between the Materials and Manufacturing Directorate and Systran Federal Corporation developed a real-time communications service called ORB_IT. ORB_IT resolves heterogeneous platform issues and provides end users with seamless reliability that makes enterprise-wide data processing as simple as performing data processing on a personal computer. The service hides all the details of the corporate network from the user.

Background Data processing in the heterogeneous manufacturing information systems environment is cumbersome and time consuming. In many enterprises, including the government, users characterize this environment by dissimilar computer hardware, dissimilar operating systems, dissimilar databases, and application programs written in many different languages.

When users of a system require data from the network, they spend considerable time searching for the needed data, trying to obtain the data in the proper electronic form. In such a highly heterogeneous environment, an employee may find data processing, using all the complete sets of enterprise data, to be extremely cumbersome unless sophisticated software, such as ORB_IT, is available.

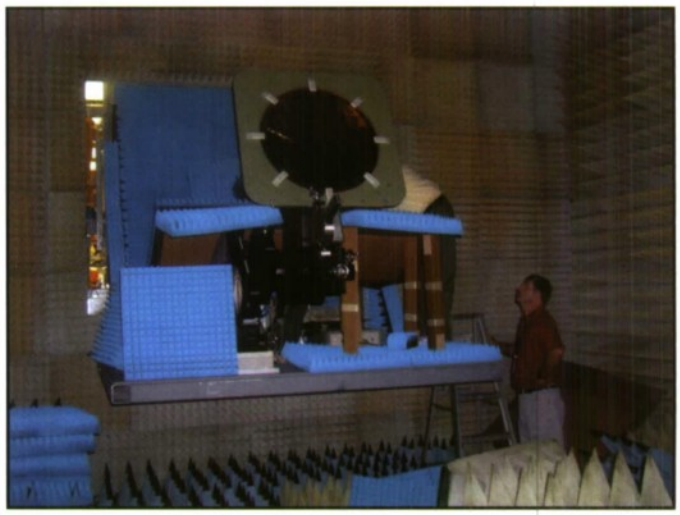
ORB_IT software is multilayered and consists of several modules such as Object Transport Layer (OTL), Data Exchange (DE), Portable Binary Input Output (PBIO), and Threads. OTL is a key module since it is responsible for transporting all object invocations and responses. DE and PBIO are software packages needed for connection establishment between clients and server applications, and for performing data marshaling. Systran designed ORB_IT to work with system threads (including real-time system threads) and user-level threads.

Multi-Spectral Scene Generation Demonstration Funded by the Central Test and Evaluation Investment Program

Payoff The ability to evaluate the performance of multi-mode (radio frequency/infrared [RF/IR]) guided munition seekers in a laboratory environment will greatly enhance the development of future munitions while reducing the cost of test and evaluation.

Accomplishment The Munitions Directorate teamed with the Naval Air Warfare Center Weapons Division and the United States Army Aviation and Missile Command to develop and demonstrate hardware-in-the-loop capabilities for evaluating multi-mode weapon sensors. Each service equipped their facility with a unique system specifically tailored to meet their test and facility requirements. In October 2000, a demonstration at Eglin AFB, Florida involved the projection of an airborne target simultaneously, in both long-wave IR and X-band RF, moving across the field of a common bore-sighted, dual-mode sensor, which detected the relative angular position of the target. The directorate's engineers will use the data collected and lessons learned as a baseline for future developments to transition this technology to other Department of Defense (DoD) laboratories and test facilities.

Background Development of new generations of advanced, highly capable, multi-spectral, precision-guided weapons will address advanced threat systems. These weapon systems require extensive and elaborate testing to validate their effectiveness. Simultaneously, the increasing costs of live-fire testing and environmental concerns mandate fewer complete munitions evaluations in field testing. As a result, it is essential to perform realistic laboratory tests to augment field demonstrations and ensure the success of those demonstrations actually performed.



The joint service team created the Multi-Spectral Scene Generation project, a Central Test and Evaluation Investment Program-funded project, to demonstrate the technologies required to simultaneously project combined IR and RF dynamic imagery to a guided weapon seeker in a Hardware-in-the-Loop Simulator test facility.

Each service was primarily responsible for a different development area under the project. The Air Force provided the IR scene projection assets, the Army provided the scene generation capability, and the Navy worked beam combiner technologies.

The directorate reconfigured their Radio Frequency Target Simulator test facility by integrating the existing X-band RF array wall with a long-wave IR scene projector, RF/IR combiner, and surrogate dual-mode seeker composed of a quantum-well focal plane array camera and a conformal array RF antenna. Hardware-in-the-Loop Simulator test facility personnel performed many years of continuous development on the directorate's IR resistive array scene projection technology. The directorate, recognized as a world leader in the development of IR scene projection technology, continues to support the needs of the DoD laboratory and test communities.

Flexible and Survivable Non-Volatile Memory Data Recorder

Payoff The Munitions Directorate developed a dedicated high-performance, non-volatile memory data recorder to improve flexibility over systems currently available. The directorate merged two different state-of-the-art, non-volatile memory technologies with reduced instruction set computer microprocessor technology to remove the need for the data recorder power source to survive for a relatively long duration after impact.

Accomplishment The directorate contracted with Thomson Thorn Missile Electronics, Ltd. of the United Kingdom, to develop a non-volatile memory data recorder for the electronic control module (ECM) of the Multiple Event Hard Target Fuze (MEHTF) program. The directorate demonstrated impact shock survivability in MEHTF gun tests when the ECM units, which employ the same technology as the data recorder, survived multiple supersonic concrete impacts. The recovered data from these tests demonstrated that the technologies operated correctly and provided stable recorder characteristics during the impact shock conditions.

The directorate proved the application of the technologies for data storage and provided evidence that the design will operate during and after successive applications of high-gravitational environments. A number of possible physical arrangements are available, depending on the probable use of the units and their requirements for built-in accelerometers. In order for the design to provide maximum applicability in munitions testing, engineers will package the electronics in a smaller volume, allowing easy location in a standard three-inch fuze well booster cup assembly. In addition, further engineering of the data recorder software will allow a wide range of recording modes required for typical munitions gun tests.

Background In the world of munitions testing, high-gravitational constant impact conditions place special constraints on test equipment. In order to obtain useful data from gun tests, data-logging devices must meet several requirements. They should be easy to set up and small enough to fit in the limited space available in impact test vehicles. They should have an adequate range of inputs to store anticipated data and be flexible enough to permit the storage parameters of the unit to capture a wide range of possible signatures. They should operate under the extreme shocks present in gun test impacts with unmodified response characteristics, retain the data after the impact, and be reusable.

Current data recorder technologies address some of these requirements, however, they contain volatile memory, which must be maintained using a power source until the data is removed from the recorder and processed. Locating penetrators after testing can be difficult; therefore, it is undesirable to sustain a power source until the projectile is located. A recorder that contains non-volatile memory would be more beneficial since this type of memory does not require a sustainable power source after the penetration event is complete.

Windows-Based Application Brings 3-D Visualization of Munitions to Desktop PCs

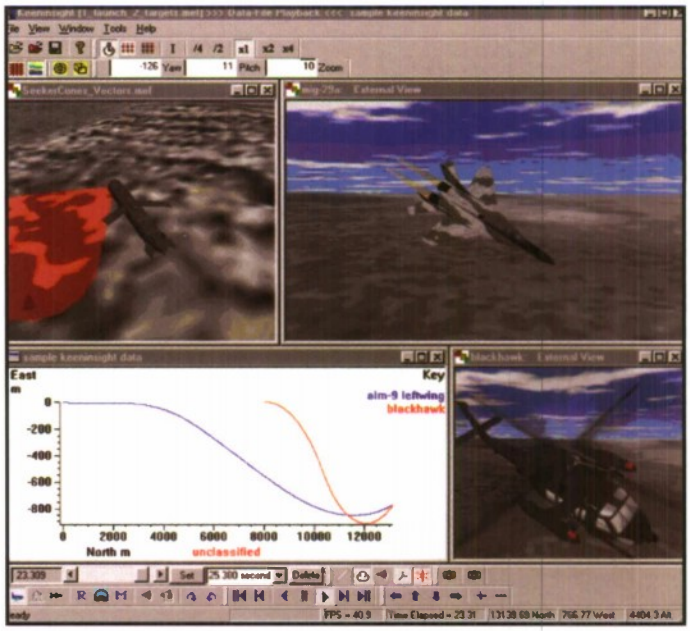
Payoff The three-dimensional (3-D) visualization analyzer, known as KeenInsight™, successfully brought 3-D visualization to desktop Windows® personal computers (PCs). KeenInsight proved that creating flexible munition in-flight visualization need not be complicated or take much time. KeenInsight creates realistic in-flight visualizations using current PC graphics hardware.

Accomplishment FAAC Inc., recently delivered a novel 3-D visualization analyzer called KeenInsight to the Munitions Directorate under an ongoing Phase II Small Business Innovation Research effort. FAAC, Inc. also successfully transitioned this graphics technology to the commercial vehicle driver-training simulator markets for the Department of Defense as well as the private sector.

FAAC personnel incorporated the PC graphics technology into the simulators that were delivered as part of the United States (US) Marine Corps Medium Tactical Vehicle Replacement-Training System, Operator Driver Simulator. The PC graphics-based simulators provide low life-cycle costs and easily maintainable systems.

In addition, FAAC sold simulators using the same PC graphics technology to the private sector. The company is also integrating the PC graphics technology into the multi-spectral man-in-the-loop cockpit simulator developed for the Guided Weapon Evaluation Facility at Eglin Air Force Base.

Background FAAC, Inc. designed KeenInsight to give the creators of munition in-flight simulations at the directorate's Guidance Simulation Branch the ability to quickly create 3-D visualizations on their desktop PCs. This application proves 3-D visualization is useful for three phases of the in-flight simulation process: (1) test/debug, (2) analysis, and (3) presentation. The directorate actually used KeenInsight to support the test/debug phase of this project during the evaluation period.



KeenInsight uses information produced off-line (by engineering simulations or other suitable sources) to provide a graphical interactive depiction of real-world engagements involving 3-D entities representing launchers, weapons, and targets. KeenInsight operates on a PC running a Windows operating system (Windows 95/98, NT® 4.0, and 2000) and is easy to use.

KeenInsight is a valuable tool in the development and analysis of future weapon systems, and the cost savings are immense since KeenInsight is freeware for the US Government. Interested agencies may contact Michael Vanden-Heuvel at (850) 882-8195 IC 3214 or email: vandenm@eglin.af.mil. Individuals outside the US Government are encouraged to contact FAAC, Inc. directly for shareware versions.

Small Business Innovation Research Program Grows

Payoff Congress mandated the Small Business Innovation Research (SBIR) program in the late 1980's and recently renewed the program until fiscal year 2008. The program grew from a few million dollars to $200M. Throughout its history, the Air Force has taken the lead in its part of the Department of Defense (DoD) program, introducing many management initiatives to help manage this growth.

Accomplishment Within the past few years, the Air Force (AF) established the AF SBIR Program Management Team within AFRL headquarters. Program managers and contracting officers in every AFRL technology directorate and at every product, test, and logistics center in the Air Force support this team.

The team instituted the allocation of the majority of SBIR topics to the Program Executive Officers and the Designated Acquisition Commanders. This move provides increased opportunities for SBIR topics to become more than just research and development projects. The SBIR team now ties the topics to operational technology requirements. This, in turn, should result in an increase in commercialization of the technologies through technology transition.

Background The AF manages the largest SBIR program within the DoD (AF $200M, Navy $125M, Army $110M). AF SBIR accounts for over 700 contracts each year. With this growth in program breadth and scope, SBIR required improved communication and management tools for field managers.

On the communications side, the team created the quarterly Air Force SBIR Advantage newsletter for people in senior positions in the science and technology community and in the acquisition community in both the AF and DoD. The newsletter's purpose is to make SBIR more accessible and to quickly disseminate information about program philosophy and program changes.

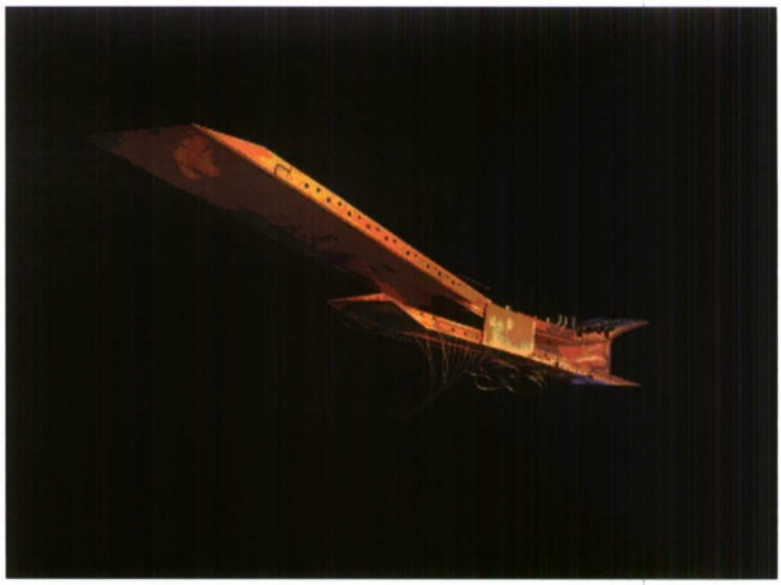
For management tools, the team created the web-based SBIR Manager's Desk Guide. This is a detailed description of all the processes, lessons learned, and best practices in order to make the field manager's job easier. The team updated the SBIR database, adding many features to enhance usability. The team also developed a new web-based tool for sharing ideas of potential topics. This tool doubles as the topic submission module, thereby reducing the need for reams of paper.

For additional information, please check the AF SBIR web site at *http://www.afrl.af.mil/sbir/index.htm* and the AF SBIR intranet site at *https://aftech.afrl.af.mil/sbir/index.htm*.

Scramjet Testing Reaches Major Milestone

Payoff A collaborative team of researchers from the Propulsion Directorate and Pratt & Whitney achieved a major development milestone in demonstrating a hydrocarbon-fueled, supersonic combustion ramjet, or scramjet engine. Such propulsive power will enable weapons that will dramatically increase range and decrease the reaction time when employed against high-value targets at long standoff ranges.

Accomplishment Built under the Propulsion Directorate's Hypersonic Technology (HyTech) program, the Performance Test Engine (PTE), an integrated engine with inlet, combustor, and nozzle, successfully completed a series of free jet tests. Pratt & Whitney developed this heavyweight, heat-sink demonstrator engine under contract to the directorate. The directorate conducted the tests in the GASL facilities at Ronkonkoma, New York. The PTE met or exceeded performance goals.



The next step and culmination of the HyTech program will be the flightweight ground demonstration engine. Pratt & Whitney will fabricate this integrated scramjet engine with fuel-cooled structures to demonstrate the performance, operation, and structural durability of this flight-type test engine.

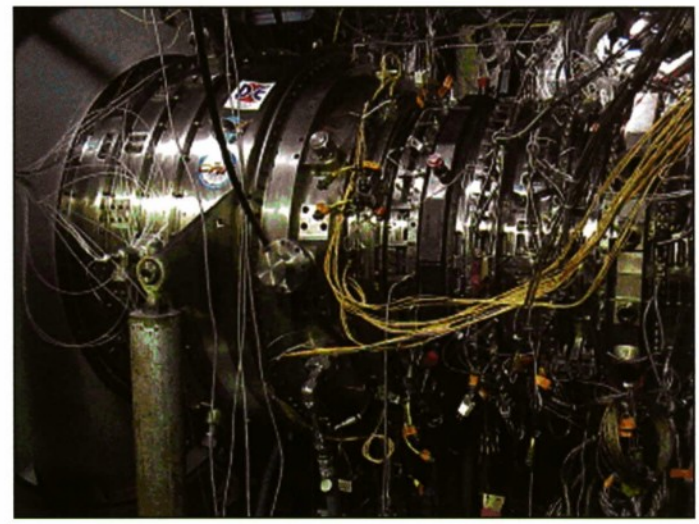
Background The HyTech program is the latest in a long series of Air Force efforts to prove the viability and utility of the scramjet engine. The program establishes a scramjet technology base with near-term applications to hypersonic cruise missiles. The directorate can expand this technology base to include reusable hypersonic vehicles such as strike/reconnaissance and affordable access to space vehicles.

By maturing scramjet propulsion, researchers will provide a key component to a new breed of propulsion systems known as the combined cycle engines. These engines, made from some combination of turbine, ramjet, scramjet, and rocket engines, use each of the different cycles to the fullest advantage of their respective efficiencies to optimize overall system performance. Such propulsion systems have the potential to enable a family of vehicles, including global range, high-speed aircraft, and spaceplane-type vehicles, for on-demand access to space.

Compressor Demonstrates Technology for Advanced Family of Turbine Engines

Payoff The Propulsion Directorate successfully tested a turbine engine compressor representing nearly 20 years of research at the directorate's Compressor Research Facility. New technologies incorporated in this compressor demonstrate dramatic performance gains over existing operational engines and will lead to high-performance, high-efficiency engines for both military and commercial users.

Accomplishment Built by team member Pratt & Whitney, this compressor represents an Integrated High Performance Turbine Engine Technology (IHPTET) Phase III compressor, the final phase of this multi-year effort. This 4-stage compressor does more work, more efficiently than the 10-stage compressor currently installed in the F100 engine of the F-15 aircraft. The compressor performs with a drastically reduced parts count and reduced overall engine length and weight. To accomplish performance gains, the IHPTET team incorporated advances in compressor aerothermodynamics, understanding of secondary flow losses, high stage loading approaches, advanced structural and manufacturing concepts, and advanced materials. These improvements benefit all end users, military and commercial, by reducing maintenance and acquisition costs.



Background The IHPTET program is an ongoing national effort to double United States military aircraft propulsion capability. The IHPTET team coordinates the gas turbine engine research and development activities of the Army, Navy, Air Force, National Aeronautics and Space Administration (NASA), Defense Advanced Research Projects Agency, and six US turbine engine manufacturers.

IHPTET team member, NASA Glenn Research Center, provided computational fluid dynamic simulations in support of this test. Researchers used the NASA/Glenn-developed multistage turbomachinery code, APNASA, to quantify design changes that will ultimately lead to more improved compressor performance.

According to sources at Pratt & Whitney, the engine manufacturer will use derivatives of this compressor in engines such as the PW7000 developed for military users and the PW6000 for commercial users. An additional IHPTET demonstration of this compressor technology will involve the Advanced Turbine Engine Gas Generator core, designated XTC67/1, in early 2001.

IHPRPT Phase I Solid Boost Demonstrator a Success

Payoff An aggressive 23-month Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program recently resulted in a highly successful full-scale solid rocket motor demonstration. The Propulsion Directorate and Thiokol Corporation jointly funded the program.

Accomplishment The Phase I Solid Boost Demonstrator program demonstrates new technologies for the case, propellant, nozzle, and control technologies in a 92 in. diameter, 120,000 lb class motor. This motor contained the most recent technologies of any one demonstration since the Trident I (C4) 25 years ago.

Preliminary data indicates meeting or exceeding all program goals. These technologies demonstrate the potential to yield a 23% increase in payload capability at a 32% lower cost for solid booster space lift applications.

These technologies are now ready to transition into small and large launch vehicles as stages or strap-on boosters, and defense missiles. Building off the success of Phase I, the second phase of this program is currently under way.

Background This IHPRPT program demonstration is part of a three-phase, government- and industry-coordinated effort that began in 1996 with the goal to double propulsion capability by 2010. A demonstration, held at the end of each of the three distinct phases, shows the achievement of goals.

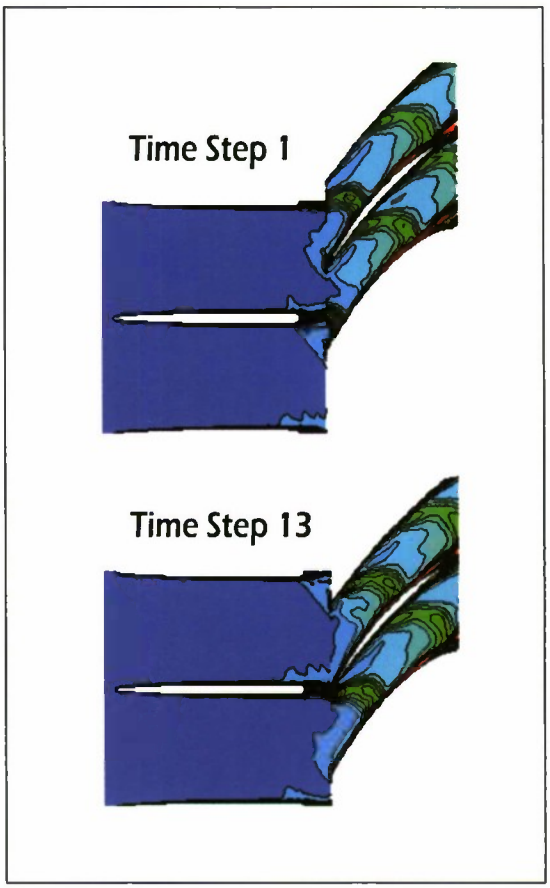
The Solid Boost Demonstrator program represents the climax of years of materials development, design, and analysis work performed in partnership between the directorate and industry. IHPRPT is an excellent example of talented people working together as an integrated team to achieve an aggressive objective.

Advanced Compressor Design Benefits from First Demonstration of New Modeling and Simulation Code

Payoff The Propulsion Directorate's Turbine Engine Division is making significant advancements in the modeling and simulation of unsteady flows for advanced turbine engine compressors. This new, in-house capability enhances the directorate's ability to deal with the complex and challenging flows associated with high-performance compressor designs. This capability will help directorate engineers achieve the goal of the Integrated High Performance Turbine Engine Technology (IHPTET) program to double the propulsion capability of turbine engines by 2005.

Accomplishment The directorate's Compressor Research Group successfully applied an unsteady three-dimensional Navier-Stokes computational fluid dynamics code to model a research compressor. This is the first in-house demonstration of this advanced code. The code, called MSU TURBO, is a three-dimensional, viscous, time-accurate code that solves the Reynolds Averaged Navier-Stokes equations in Cartesian coordinates in a rotating frame of reference. Directorate scientists are using the code to model the stage matching investigation (SMI) rig recently tested in the directorate's Compressor Aero Research Lab.

Experimental data from the SMI rig test shows that axial blade-row spacing affects the rotor efficiency and pressure ratio. Directorate engineers use MSU TURBO to model the unsteady interaction between the stator and the transonic rotor in an effort to understand the flow physics driving the change in compressor performance with axial blade-row spacing. The code ran on a Cray supercomputer at the Naval Oceanographic Office Major Shared Resource Center and took 225 hours of central processing unit time to reach a converged solution.



Background IHPTET is a national program coordinating the efforts of the Air Force, Army, Navy, National Aeronautics and Space Administration, and major United States gas turbine engine manufacturers. To meet IHPTET goals and the follow-on program's (Versatile Affordable Advanced Turbine Engines) goals, directorate engineers are designing fans and compressors with increased stage loading and closer axial blade-row spacing.

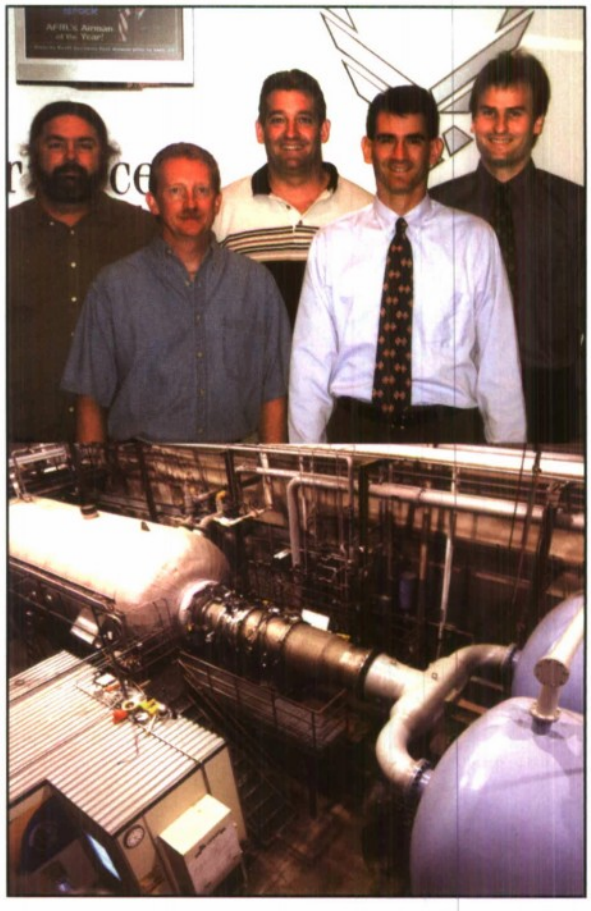
The understanding of unsteady blade-row interactions has a significant impact on performance attainment and prevents high-cycle fatigue failures. Accurate analysis of these complex fields is imperative to understand the flow physics of these compressors in order to design the high-performance and durable compression systems for advanced turbine engines.

Successful Test Represents Leap Forward for Air Force Turbine Testing Capability

Payoff A team of researchers from the Propulsion Directorate completed the first true performance test of the uncooled high-pressure turbine for the F119 engine used in the F-22 air superiority fighter. The Air Force now has the ability to verify turbines designed for their warfighters.

Accomplishment Using the directorate's Turbine Research Facility (TRF) to make fifty runs, researchers applied the resulting data to create a complete operating map of the turbine. The researchers varied parameters, such as pressure ratio, Reynolds number, corrected speed, and temperature, in these runs.

The researchers acquired detailed surface pressure measurements and surface heat fluxes in these runs as well as overall aero performance data. This data, compared to design predictions, will help researchers analyze the F119 turbine performance by providing benchmark aero thermal data used to calibrate computational fluid dynamics (CFD) codes.



Background Turbine failure in a jet engine is costly. Predicting performance of advanced turbine designs is difficult and expensive. Prediction depends on the quality of the predictive tools, which, in turn, depend on the quality of test data. For the F119 turbine test, the directorate research team solved a number of issues enabling them to generate exceptionally high quality test data. This project focused on the tip and shroud region of the turbine blades because only very limited experimental data in this region exists for a fully rotating rig.

The TRF can generate accurate torque measurements, remove the approach boundary layer flow prior to entering the test section, accurately control the corrected speed of the turbine, account for "g" field effects on pressure transducers, and eliminate oscillations in the flow field due to starting transients. Collectively, these capabilities provide safe, reliable, and highly accurate testing, which represents true performance testing for turbine stages. The Air Force now has the tools to fully understand the unsteady flow fields generated in turbine engines.

The highly accurate, high-frequency response pressure and heat flux measurements of the TRF now allow the technical community to better understand the physics of these complicated flow fields. Based on this improved understanding, researchers can calibrate CFD codes to higher accuracy and, hence, more accurate predictive capabilities. With more accurate predictive tools, researchers can create more durable and less costly turbines for future advanced engines while improving our understanding of currently installed engine performance.

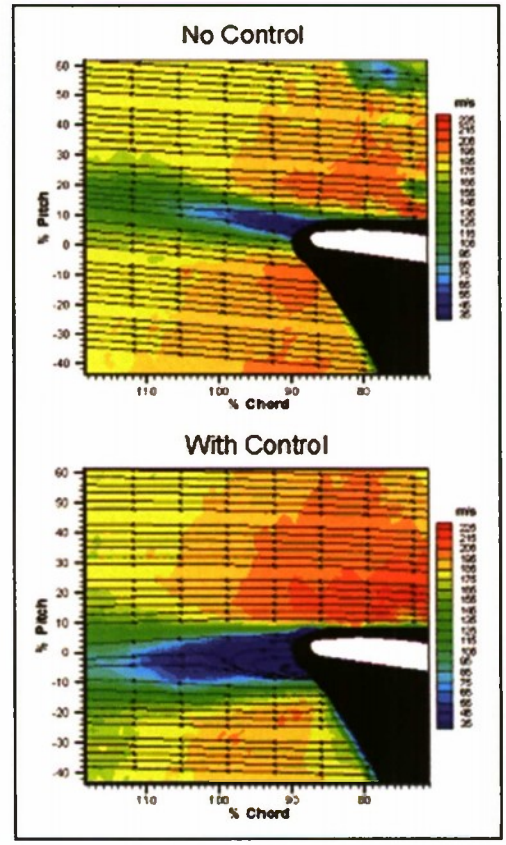
Propulsion Directorate Achieves Non-Mechanical Cascade Airflow Vectoring

Payoff Scientists from the Propulsion Directorate's Fan and Compressor Branch, in collaboration with Virginia Polytechnic Institute and State University (Virginia Tech), demonstrated an airflow control technique with application to future compressor designs. This technique, if successfully applied to future turbine engines, should reduce the number of engine parts, significantly lower overall engine weight, and reduce overall engine cost.

Accomplishment The directorate and the Virginia Tech team demonstrated the first-ever counter-flow-blowing-based flow vectoring in a high through-flow Mach number stator cascade. Virginia Tech tested the cascade in their "blow-down wind tunnel" facility as part of this collaborative effort. By placing a blowing jet on the pressure side surface of the cascade blade near the trailing edge, researchers vectored the passing airflow and provided flow control without mechanical parts.

Background Current jet engine fan designs, in many cases, require flapped inlet guide vanes and variable stators to ensure correct inlet flow conditions during off-design operation. Every stator blade in the compressor section must be coupled mechanically to all other stator vanes in a stage and then, in turn, to an actuating mechanism. This is a complex and heavy aspect of current compressors.

Through these connections, research engineers can change stator blade angle-of-attack (relative to incoming air) to control engine airflow. The ability to vector the flow without the need for this mechanical complexity reduces both the number of parts and overall weight of the compressor.



Instead of a complex mechanism to vector the airflow in the test cascade, directorate scientists employed blade pressure side surface counter-flow "blowing" to increase blade circulation and achieve considerable flow vectoring. Increasing the circulation increases the pressure distribution on the stator and turns the airflow.

For this demonstration, directorate engineers placed the blowing jet on the pressure surface of the blade near the trailing edge and directed it into the main flow direction, that is, a counter-flow direction. The engineers directed the blowing as tangent to the blade surface as possible.

The results of this technique, as illustrated in the photos, clearly demonstrate that the blowing caused an increase in the amount of flow turning from the baseline. Directorate engineers achieved this result in the test by counter-flow blowing at a level of 1% of the air passing through the cascade.

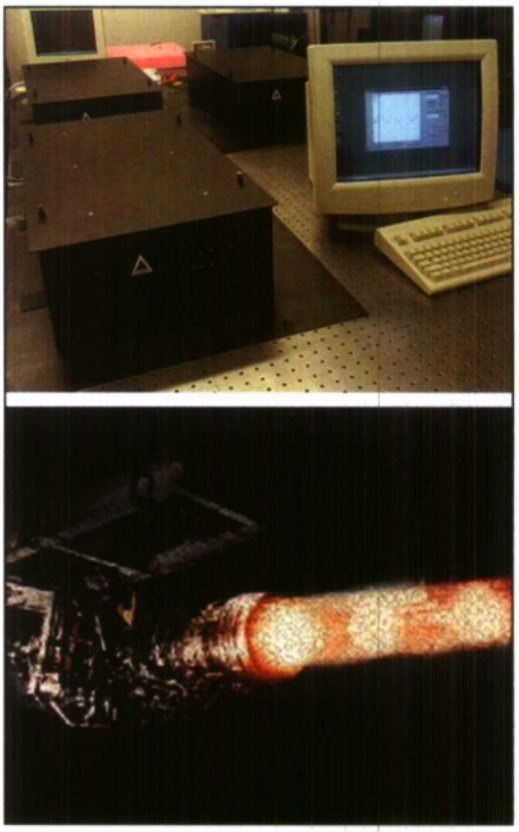
When measured using the particle image velocimetry technique, this 1% case resulted in a 9° flow turning. Based on these results, the directorate anticipates achieving even greater levels of flow vectoring, leading to higher efficiency and lower weight compressor designs.

Laser Source Enables Sensitive Gas Concentration Measurements for Aircraft Engine Combustion Tests

Payoff Diode-pumped optical parametric oscillators provide a compact, tunable, room-temperature, mid-infrared light source, which is useable as the basis of a multi-species gas sensor for Air Force combustion diagnostics. These oscillators may improve engine efficiencies through studies using such a sensor, and engineers may use similar techniques for pollution/industrial process monitoring and electro-optical targeting sensors.

Accomplishment Funded by a Phase II Small Business Innovation Research award from the Sensors Directorate, Aculight Corporation in Bothell, Washington, incorporated customer feedback from the Propulsion Directorate and developed a novel, room-temperature, mid-infrared laser source for combustion diagnostics applications. Aculight engineers demonstrated prototype computer-controlled sources operating at four different wavelength ranges from 2.2 to 3.7 microns.

Aculight delivered the prototypes to the Propulsion Directorate for test and assessment in combustion diagnostics experiments. They also supplied similar sources to a commercial company and to the National Institute of Science and Technology for tests in highly sensitive, cavity ringdown species measurements. The world's foremost laser conference hosted a presentation of this groundbreaking work as a postdeadline paper.



Background The infrared spectroscopy source is a periodically poled lithium niobate (PPLN)-based optical parametric oscillator pumped directly by a near-infrared semiconductor laser. This PPLN-based source produces narrowband (5 MHz) radiation in the 1 to 4 microns wavelength range.

This wavelength range, where absorption features exist for many species of great interest in combustion science and trace species measurement, previously required semiconductor lasers cooled by liquid nitrogen. By contrast, this new source retains the attractive features (compactness, tunability, and robustness) of the semiconductor laser while operating entirely at room temperature and above.

Electronic Devices Fabricated Using Nitride-Based Material

Payoff The Sensors Directorate in-house project teams are investigating nitride-based technology. These teams leverage in-house capabilities, contractual efforts, commercial developments, and diverse funding sources in a collaborative and complementary program of technology development. New nitride-based devices can potentially reduce system level aperture size by 1.8 times and improve range by 80%. This technology will also improve efficiency by a threefold reduction of prime power and thermal management and a twofold reduction in mass and volume, and will reduce the overall cost of the aerospace subsystems.

Accomplishment A team of scientists from the directorate, industry, and academia investigated fabricating electronic devices using nitride-based material. The collaboration achieved a record output power of 40 watts (W) at 10 gigahertz from a single solid-state device (greater than 2.5 times conventional) and record power density of 9.8 W/mm (greater than 10 times conventional).

Background Unlike conventional technology using silicon or gallium arsenide, nitride-based devices are more robust when exposed to extreme temperature and radiation environments. In addition, the unique properties of nitride-based devices help them sustain very high voltages, typically more than 200 V, and high current densities greater than 1 amp per mm. Therefore, nitride-based devices should operate under direct exposure to a harsh environment while also subjected to hostile input signals.

Advanced unmanned air vehicles and space platforms need electronic devices that operate in a very hostile environment with low mass and reduced volume. Commercial industry investigated nitride-based technology for several years with particular emphasis on light-emitting diodes for lighting. The results show great promise for military applications because of their wide bandgap properties.

With increased power density, nitride-based devices also have unique power characteristics that would enhance microwave amplifier technology. Leveraging commercial industry research, the directorate initiated an in-house nitride device project team to examine the possibilities of a robust nitride-based technology for critical military applications.

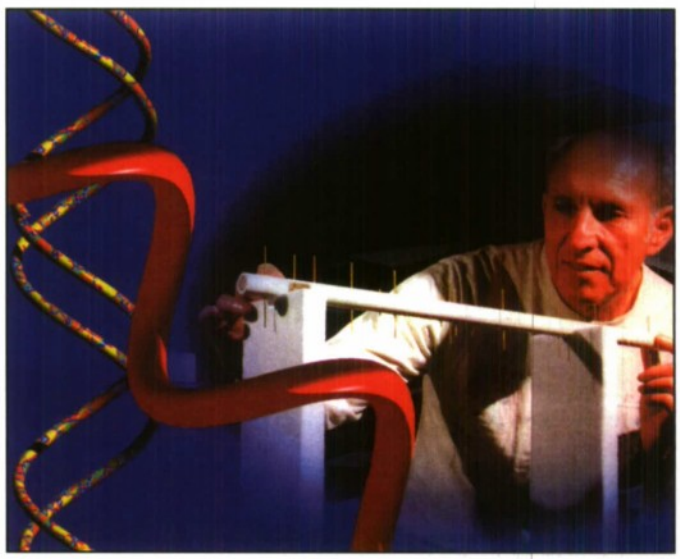
Nitride-based devices, when inserted into sensor applications, should enable new operational capabilities for the warfighter. These systems require limited volume, reduced mass, and limited environmental control, and include examples such as Sensor Craft, unmanned air vehicles, space-based radar, communications links, and electronic warfare. The characteristics noted offer a solution to the technical barriers associated with radio frequency apertures.

Genetic Algorithms Improve Antenna Performance

Payoff As the Air Force migrates to space, Sensors Directorate researchers recognize an emphasis on increased antenna performance. Using genetic algorithms for antenna design generates antenna configurations never before seen. Genetic algorithm technology provides a deeper breadth of antenna design, saving time and, consequently, money in the development of new antenna technology.

Accomplishment Directorate researchers refined a well-known optimization technique for antenna design through an in-house research and development effort. Genetic algorithms allow researchers to develop antennas that outperform those previously available. The success of this research resulted in the award of US Patent No. 5,719,794, entitled "Process for the Design of Antennas Using Genetic Algorithms."

Background A variety of wire antennas exist including dipole, monopole, rhombic, the beverage, the yagi, the log-periodic, the loop, the helix, and the spiral antenna. The design of these antennas relied mainly on the use of trial and error techniques. Researchers, using ingenuity and intuition, created a better antenna, or used existing antenna configurations, to apply changes until they obtained an acceptable design.



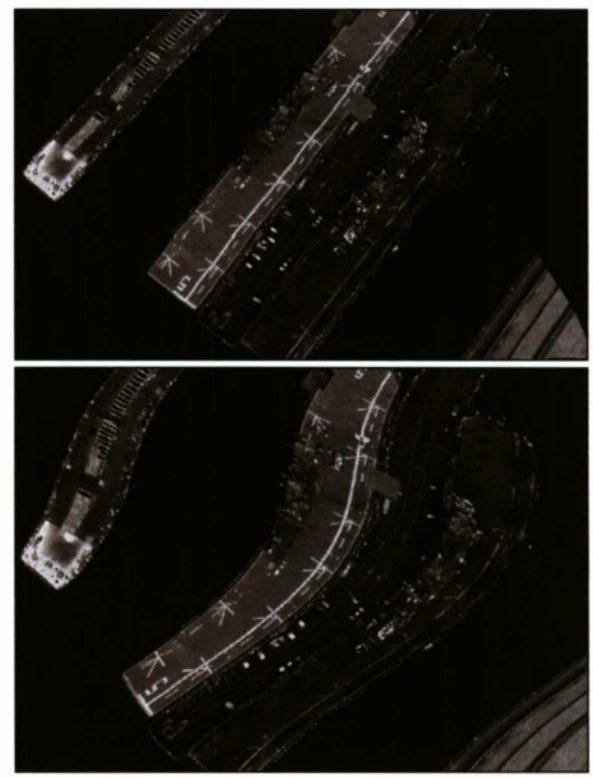
The increased need for improved performance led to the innovative use of genetic algorithms. This mathematical phenomenon, first investigated in the 1970s, had limited application because it needed greater computational capabilities. The availability of high-speed computers permits researchers to use the genetic algorithm for many new applications including antenna design.

In this process, the engineer specifies the desired antenna parameters using a synthesis approach, then the genetic algorithm attempts to find the best antenna configuration for the intended application. A genetic algorithm randomly selects several hundred possible configurations from a very large population and identifies each configuration by a chromosome (a string of zeros and ones).

Automated Motion-Compensation and Semi-Automated Restoration Techniques

Payoff Unavoidable variations in aircraft speed, direction, altitude, and orientation introduce distortions, which reduce the usefulness of electro-optical (EO) and hyperspectral imagery acquired from line-scan sensors. The Sensors Directorate developed automated motion-compensation and semi-automated techniques that restore distorted images caused by failure of camera stabilizers, incomplete data due to sensor failure, or unavailable geographic reference and navigation data.

Accomplishment Directorate engineers developed automated motion-compensation and semi-automated restoration techniques that greatly reduce distortions with line-scan images caused by variations in the motion and orientation of sensor platforms. Directorate engineers successfully demonstrated these techniques on highly distorted, high-resolution EO infrared sensor and hyperspectral sensor images.



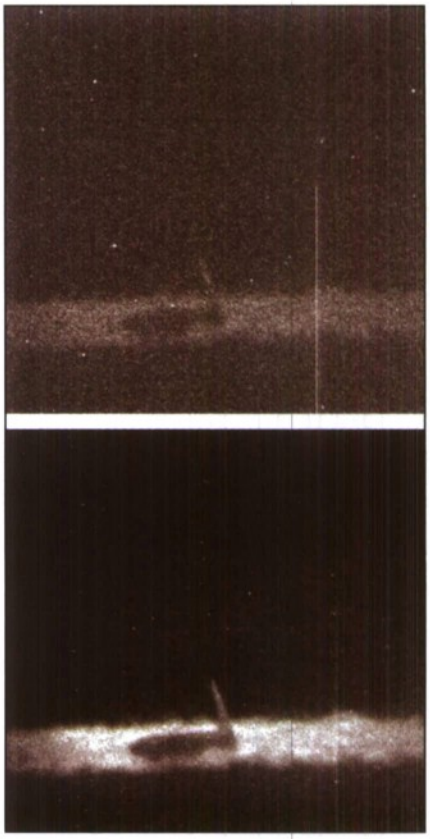
Background Images acquired from aircraft-mounted line-scan sensors are subject to distortions caused by changes in platform speed, direction, orientation, or altitude. Even with camera stabilizers, aircraft movements create distortions in line scans. These distortions can reduce the ability to identify characteristics of objects or make the objects completely unrecognizable. For example, when an aircraft begins scanning a building at one altitude, then climbs to a higher altitude before completing the scan, the width of the building appears to become progressively narrower over its length.

Directorate engineers achieved a compensated image for the EO imagery on highly distorted images by applying a matched filter to each line. For hyperspectral imagery, the directorate completed an optimally matched filter from selected frequency bands, then propagated it through the other frequencies. The engineers successfully demonstrated the line scan-matched filter even when camera stabilizers failed, when no geographic reference or available navigation data existed, and when sensor failure resulted in incomplete data.

ERASER - Enhanced Recognition and Sensing Radar Sensor

Payoff A new image enhancement technique increases sensor identification ranges, allowing pilots to target and attack from greater standoff ranges, thereby reducing aircrew and aircraft risk. Computation improvements should increase the identification range performance of the Enhanced Recognition and Sensing Radar (ERASER) sensor by a factor of two or more for the observer and/or the automatic recognition and cueing systems. The algorithm developed during this project has great transition potential for imaging sensors used and developed by the Air Force.

Accomplishment A team of researchers from the Sensors Directorate, Wyle Laboratory, and Optimetrics developed image-processing software to enhance the image quality and performance of a new laser identification technology known as the ERASER. ERASER uses a laser to illuminate the target area and a high-resolution camera to collect the reflected laser energy and obtain a clear picture of the area. ERASER increased the identification range with no additional hardware modifications. The team also developed a computer model that predicts the performance of the ERASER for a variety of atmospheric, sensor, and laser combinations and scenarios.



Background Previous laser radar technology generated images much like a television with two mirrors scanning a laser beam and building the picture one pixel, or picture element, at a time. This technology is only suitable for short-range applications. The cost of beam pointing and stabilization at longer ranges is prohibitive for scanning systems.

Instead of building an image one pixel at a time, ERASER works like a regular camera taking a snapshot of the potential target area. New algorithms provide electronic image stabilization using pixel-based registration while improving image resolution using frame averaging.

Engineers used a variety of filtering algorithms to eliminate spatial noise. The engineers also minimized the computational requirements for these algorithms to allow real-time implementation using commercial off-the-shelf (COTS) processors.

The team built a COTS processor, which is compatible with the ERASER and automatic target recognition systems, to implement these algorithms for the field and flight demonstrations. The team also worked with Raytheon developing a performance model applicable to the ERASER sensor system. The team upgraded the model to provide results with a much higher confidence factor after conducting extensive research on the sensor, laser, and various atmospheric parameters.

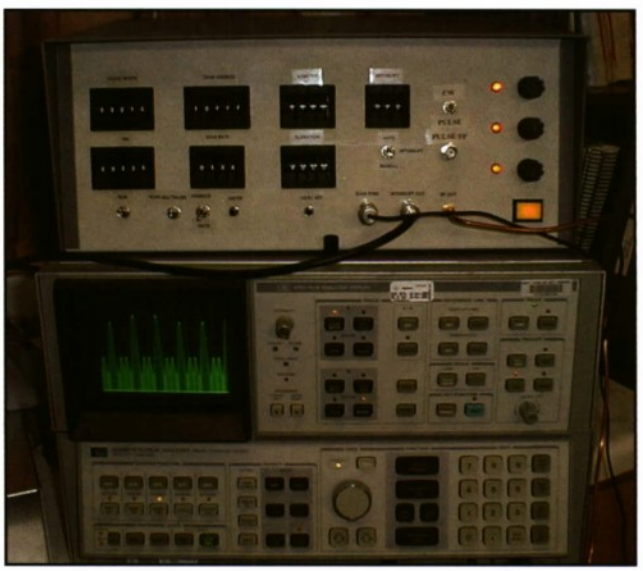
Dynamic Antenna Pattern Generation Prototype

Payoff The Sensors Directorate Integrated Demonstration and Applications Laboratory's (IDAL) new Dynamic Antenna Pattern Generation Prototype will enable radio frequency (RF) threat simulations to include emitter antenna pattern dynamics modeled on-the-fly. These RF threat simulations accurately represent antenna effects correlated with sensor platform dynamics. This will enable the directorate and future IDAL customers to continue sensor technology maturation in a controlled laboratory environment prior to entering flight test.

Accomplishment Directorate engineers, in conjunction with ITT Industries, Avionics Division, designed and built a Dynamic Antenna Pattern Generation Prototype. The prototype models the dynamics introduced by emitter antenna movement relative to changing sensor platform dynamics (e.g., aircraft maneuvers).

Directorate engineers used a specialized dual-port memory controlled by a complex programmable logic device and an embedded microprocessor to achieve programming flexibility and design goals. Engineers will use this intricate prototype to explore simulation algorithm and implementation alternatives necessary to satisfy the next generation simulation needs for precision targeting/location/identification systems. Examples of such systems include the directorate's Precision Location and Identification and Advanced Tactical Targeting Technology programs.

Background The directorate developed RF-level simulation technology to support research and development, and technology insertion. As sensor technology changed and adapted to new and differing requirements, the IDAL successfully modified, extended, and developed new RF-level simulation technology and techniques. This ensures sensor technology matures in the laboratory prior to progressing to the flight test environment.



Directorate engineers successfully proved the methodology of risk mitigation through laboratory demonstrations over the years. Thus, the Department of Defense adopted this methodology as an essential tenet of the electronic combat test process.

Previous RF simulation architectures used static, target-centric antenna pattern generation methods sufficient for currently deployed sensors. New sensor designs, incorporating improved receiver sensitivity levels and increased signal analysis capabilities, will require far greater fidelity for generating accurate system-of-systems synthetic battlespaces.

The Dynamic Antenna Pattern Generation Prototype addresses the impact of sensor platform movement on simulating emitter antenna scan patterns. This unique design permits engineers to dynamically change simulated threat emitter patterns while eliminating pattern discontinuities normally associated with dynamic pattern rewrites. Directorate and future IDAL customers should benefit from reduced risk and costs associated with science and technology research programs and subsequent transition of sensor technology to the warfighter.

New Innovative Solid-State Digital Airborne Recorder Demonstrated

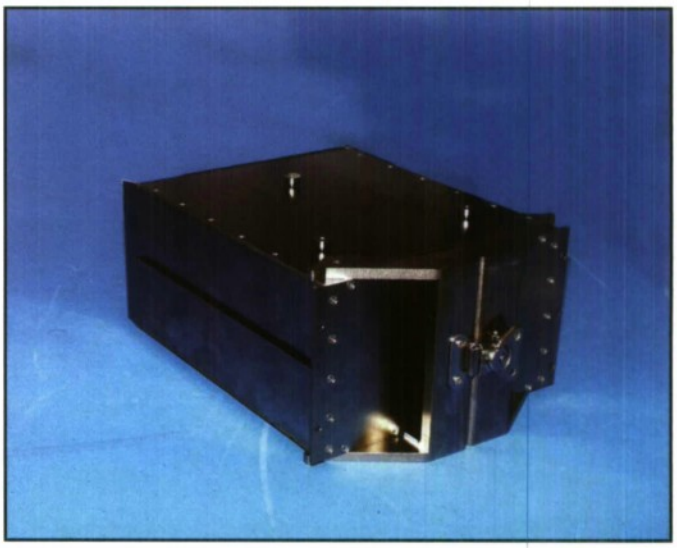
Payoff Under a Small Business Innovation Research (SBIR) program, engineers designed a scalable memory recorder with parallel record and readout capability and an innovative solid-state memory device for high-speed mass data storage. The recorder uses an open-architecture platform to interface with a wide range of sensors, imagers, analytical systems, and control systems without the necessity of system or module redesign.

The design meets the requirements for a rugged, medium-to-high bandwidth solid-state recorder. Since it uses commercial off-the-shelf (COTS) memory, the recorder will have lower life-cycle costs along with improved memory capability.

Accomplishment Using SBIR program funding, the Sensors Directorate contracted with SEAKR Engineering of Englewood, Colorado, and Systems Processes Engineering Corporation (SPEC) of Austin, Texas, to develop solid-state data recorders for airborne data storage of high capacity. The recorders, with no moving parts, have a data rate of 30 gigabytes.

These recorders also have a parallel record and read capacity with a write/readout rate of 500 megabytes per second. The use of the VersaModule Eurocard bus open architecture standard for the front end enables the design to interface with a wide variety of analog and digital input/output and data bus standards.

Background Existing video tape recorders contain 100 megabytes of memory and cost approximately $250,000. Tape recorders, though a well-established technology, have lifetime limitations through aging of both the tape and the moving tape-head mechanism, which cannot provide a simultaneous record/playback capability.



The Air Force reconnaissance community expressed an interest in replacing their tape recorders with solid-state memory devices, but current units could not meet storage capacity requirements. The directorate initiated a Phase I SBIR program to solve this problem.

After successfully demonstrating the solid-state technology, the directorate initiated a second phase. The high data rate design represents an innovative packaging and exploitation of the COTS memory market with the capability for rapid download and simultaneous record/playback. The solid-state memory consists of 512 megabyte electrically erasable programmable read only memory arranged as removable memory unit modules of eight memory cards.

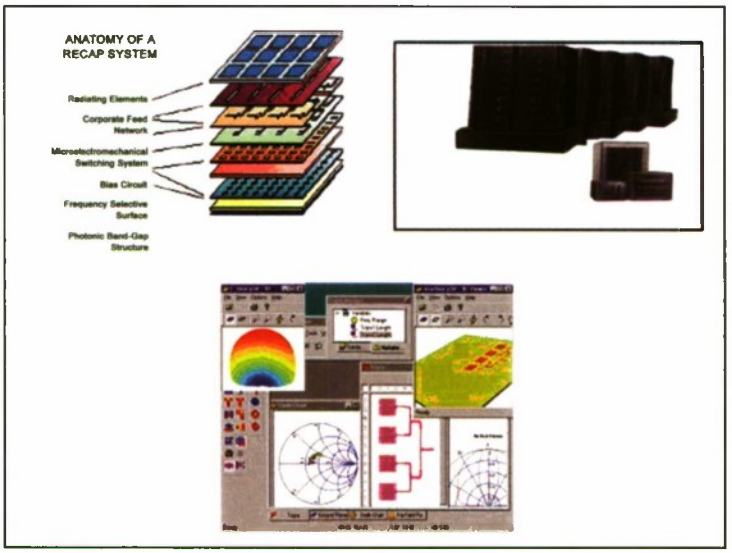
Each card provides 13.82 gigabytes of data storage for a total of 110.2 gigabytes per module. A single matrix array controller field programmable gate array mounted on the card autonomously controls erase, read, and write operations for each memory card.

Reconfigurable Aperture Antenna

Payoff The Reconfigurable Aperture Antenna (RECAP) high-performance computer-aided design (CAD) tool eliminates memory bottleneck and drastically reduces computation time. It opens the way for antenna and system designers to efficiently design highly sophisticated reconfigurable antennas.

Specifically, RECAP allows designers to deal with gigantic design trade spaces within reasonable computation times, while distributing the computational load among all the available computing resources. The RECAP design tool will be available to all tri-service Department of Defense (DoD) users through the Major Shared Resource Center High Performance Computing Modernization Office (HPCMO).

Accomplishment The Sensors Directorate, in collaboration with the Defense Advanced Research Projects Agency and the HPCMO, developed a fully parallelized high-performance RECAP CAD tool to assist tri-service DoD users with the complex task of design and prototyping of reconfigurable antennas. The CAD tool uses an array of sophisticated simulation and optimization engines along with visualization utilities.



Background Today's military sensor and communication platforms require multiple antennas to achieve the frequency bandwidth needed to complete the mission. The Air Force, Army, Navy, and other DoD agencies invested millions of dollars developing multifunction wideband antenna arrays to reduce the number of antennas.

Reducing the number of antennas results in such benefits as reduced drag, increased survivability through reduced radar cross section, and reduced electromagnetic co-site interference. This applies to ships, mobile units, land warriors, aircraft, unmanned air vehicles, and satellites.

A major cost and performance driver of a RECAP system is the lack of a fast and computationally efficient design capability. The planned parallelized RECAP design tool will dramatically expand the capability of DoD users to design large-scale reconfigurable antennas for multi-mission roles.

Ballistic Missile Range Safety Technology

Payoff Air Force Space Command (AFSPC) seeks to transition its aging space launch radars to a space-based Global Positioning System (GPS) tracking architecture. The Space Vehicles Directorate is paving the path for implementing a new technology on operational spacelift ranges.

Accomplishment A Rocket Systems Launch program flight test helped AFSPC take a big step towards achieving their next-generation space launch range vision. Florida National Guard personnel launched the Space Vehicles Directorate's Ballistic Missile Range Safety Technology (BMRST) flight experiment aboard the Space and Missile Systems Center's Quick Reaction Launch Vehicle-1 (QRLV-1) from Kodiak Launch Complex in Alaska.

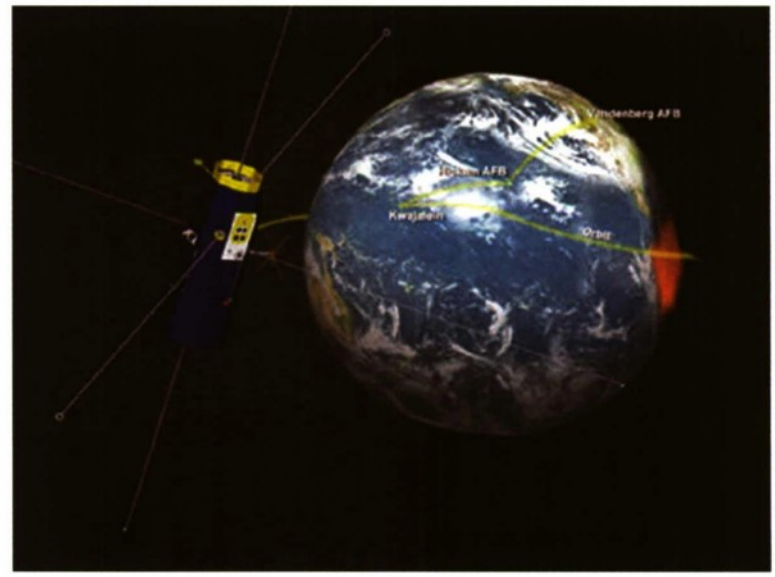
The BMRST system combines onboard GPS and inertial navigation system technology in place of heavy and bulky radar tracking transponders. The system instantly beams down the launch vehicle's position and velocity to a robust mobile range safety center.

Background The BMRST system performed flawlessly as it tracked the QRLV-1 during its seven-minute flight flown in support of the Alaskan Command's Northern Edge Exercise. In addition to the Honeywell BMRST contractor team, Florida National Guard personnel transported BMRST's mobile system to Kodiak and operated the system during its inaugural flight test.

Six-Instrument Payload Designed for Communication/Navigation Outage Forecasting System Satellite

Payoff The Space Vehicles Directorate recently completed the preliminary design of a six-instrument payload for the Communication/Navigation Outage Forecasting System (C/NOFS) satellite. This will be the first payload capable of making the full set of equatorial ionospheric measurements needed to understand and forecast naturally occurring ionospheric scintillations that cause satellite communication and navigation outages.

Accomplishment The C/NOFS payload consists of six instruments designed to probe the onset of scintillation activity through various ionospheric measurement techniques from a low-altitude, low-inclination satellite platform. Directorate researchers will input payload data into scientifically based models to generate real-time nowcasts, 1-3 hr scintillation warnings, and 4+ hr scintillation forecasts. The C/NOFS will revisit nearly the same portion of the equatorial ionosphere every 90 min to validate forecasts and observe the progress of known scintillating regions.



Background The directorate is conducting the C/NOFS program to demonstrate a brand new capability to forecast communication and navigation outages caused by ionospheric scintillation. Scintillation is a major problem because it impacts the performance of systems with radio wave links to space (< 2.5 GHz) and no reliable way exists to forecast when or where it will occur.

The directorate is currently developing the instrument payload, physics-based forecasting models, and a data processing center for product generation and dissemination. The directorate will transition the C/NOFS capability to military communication operators and other functional users at the completion of the Advanced Concept Technology Demonstration evaluation phase. The Space Test Program is providing the C/NOFS spacecraft, launch vehicle/service, and the first year of on-orbit operations.

Advanced Subsystem Technologies on the TechSat 21 Flight Experiment

Payoff The Technology Satellite of the 21st Century (TechSat 21) uses a small cluster of three low-mass satellites to demonstrate new microsatellite- enabling technologies. The experiment objectives include the demonstration of low-cost/lightweight subsystems, mass-produced spacecraft, precision formation flying, autonomous operations, aperture reconfigurations, and precision metrology. The experiment will enable multifunctional system architecture for the 21st century.

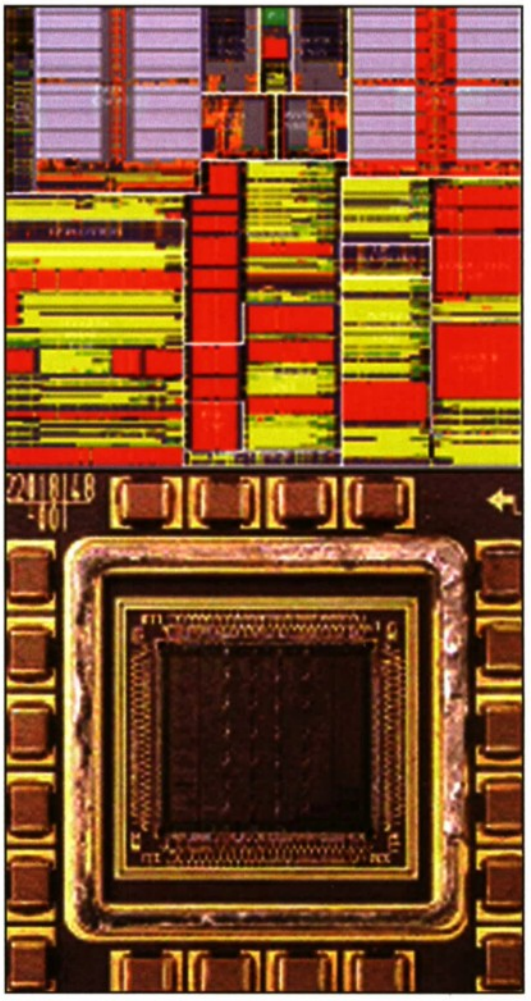
Accomplishment Space Vehicles Directorate engineers are integrating key technologies onto the three TechSat 21 spacecraft that comprise the TechSat 21 Flight Experiment. The development of microsatellite technology and exploration of distributed sensor concepts are other goals of the program.

Background Each satellite has a single Hall effect thruster that provides variable thrust, specific impulse, and 35% efficiency. The dry mass of the thruster, electronics, and fuel system is 7 kg, with 1 kg of Xenon fuel for each spacecraft. This is sufficient for a one-year operation that includes formation initialization, maintenance, and several reconfigurations. The electrical power subsystem consists of thin-film solar arrays and a lithium polymer battery that provides enough watt-hours for durations of up to 10 minutes.

PowerPC™ for Space

Payoff PowerPC™ microprocessors form the basis for space computers that use standard interfaces and run commercial software. The use of commercial standards and software makes application development much simpler and more affordable for satellite builders.

Accomplishment The Space Vehicles Directorate successfully completed the first fabrication runs on two radiation-hardened microprocessors that confirm the ability to run commercial PowerPC software. These microprocessors do much more computing with far less power than previous microprocessors, enabling smaller, cheaper, yet far more capable satellites.



Background Two competing microprocessor programs successfully passed verification testing and preliminary environmental testing. The RHPPC™ from Honeywell Space Systems is a PowerPC 603e-compatible microprocessor fabricated on the Honeywell silicon-on-insulator process. This process yields an extremely hard device suitable for the most demanding radiation environments.

The RAD750™ is a PowerPC 750™ variant from BAE Systems. The company redesigned this device using harden-by-design techniques and fabricated it on a commercial fabrication line. This approach allows manufacturers to make more advanced chips at affordable costs, yet provides sufficient hardness for most military space requirements.

Global Deployment of SCINDA Stations

Payoff To help predict communication outages caused by naturally occurring changes in the ionosphere, Space Vehicles Directorate scientists recently completed installing ultra high frequency (UHF) satellite communications (SATCOM) and Global Positioning System (GPS) monitoring stations at seven locations around the earth's magnetic equator. Directorate researchers retrieve and compile scintillation data from available satellite links and ionospheric drift velocity data via the Internet to make tri-color maps of disturbance regions. The researchers then send these maps to SATCOM and GPS users along with forecasts of likely link outages.

Accomplishment Directorate scientists demonstrated the deployment of the scintillation network decision aid (SCINDA) concept using two stations in South America (Ancon, Peru and Antofagasta, Chile) to record scintillation parameters from UHF United States Navy Fleet SATCOM and L-band (Geosynchronous Operational Environmental Satellites, GPS) satellite links. With the recent addition of five more stations in Ascension Island, Bahrain, Diego Garcia, Manila, and Guam, and in collaboration with Australia, sites at Papua, New Guinea, Indonesia, Malaysia, and North Australia, directorate scientists can now provide current, as well as forecast, SATCOM and GPS link parameters for large geographic areas. Data from this chain of SCINDA stations is providing a quantum leap in accuracy over climatological models in alerting and forecasting local scintillation occurrences and impacts.

Background Scintillation is a rapid amplitude and phase fluctuation of satellite signals observed near the earth's surface, causing link degradation or outage. The most intense natural scintillation occurs during nighttime within 20% of the magnetic equator, a region where most of the United States' recent military operations occur.

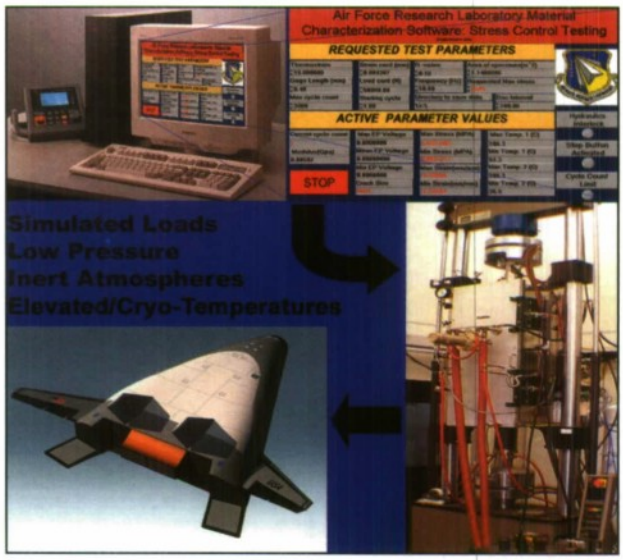
Scintillation affects frequencies up to 2 gigahertz, but its primary impact is on UHF SATCOM in the 200-275 megahertz frequency range. Very intense scintillation can also degrade GPS location accuracy by limiting the number of satellites available for position fixes.

Technology Transfer

Combined Environment Testing Software CRADA Signed

Payoff The Air Vehicles Directorate's Structures Division and MTS Systems Corporation signed a Cooperative Research and Development Agreement (CRADA) to commercialize the Air Force Combined Environment Testing Software (CETS). Each sale produces a net profit to the Air Force of $150 per commercial sale of CETS. Engineers use CETS to perform mechanical testing on materials/structures in extreme environments. The directorate and MTS share an interest in developing software that will allow simulation of Space Operation Vehicle (SOV) mission profiles.

Accomplishment The directorate's Structures Division plans to invest one third of its research budget over the next seven years in the development and demonstration of space technologies for the SOV. The Structures Division possesses unique facilities and equipment for supporting mission requirements in research and development of structural components. For example, the fatigue and fracture test facility contains mechanical and hydraulic test machines capable of supporting component testing of forces up to 500,000 lbs and an MTS environmental chamber system that simulates the atmosphere of space.



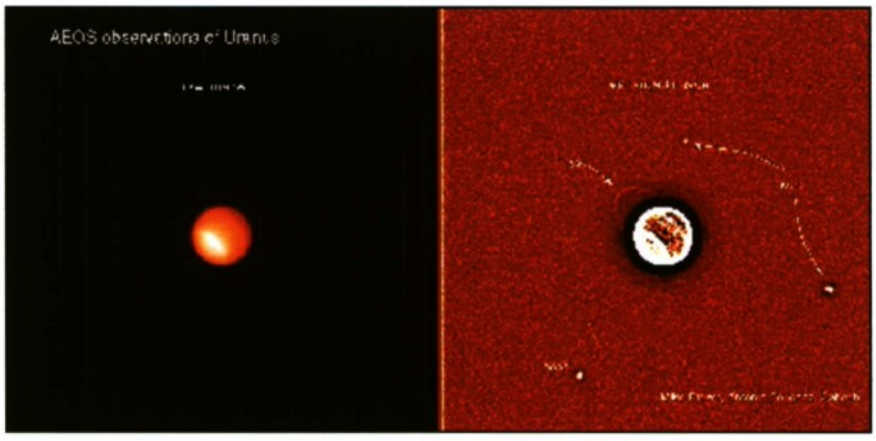
The Air Force will obtain a new MTS TestStar II system as well as repair two existing MTS TestStar II systems. The TestStar II control system is an automated digital system used to control single station, single channel closed loop dynamic testing systems. TestStar II uses graphical, mouse-driven system software to set up and manage tests and to collect data. Time-critical processes, such as closed loop control, limit detection, and data acquisition, take place in the controller firmware. TestStar II can be configured on new dymanic test systems or as an upgrade to existing MTS test systems or those from other suppliers. In addition, the Air Force will advance its testing software to evaluate next-generation air/space structures under extreme conditions.

Background Engineers use CETS and equipment manufactured by MTS to perform mechanical testing of materials and structures in a simulated space environment. CETS evaluates sub-scale designs of components under simulated operational conditions. Some critical concerns for the SOV are the thermal protection system, fuel tanks, and integrated structures, which must be lightweight and durable in order to conform to requirements. CETS will control loads, temperature, and pressure using an MTS environmental chamber system. Through control of these parameters, CETS can simulate an entire SOV mission's flight loads and temperature profiles.

Civilians Provided Access to AEOS Telescope

Payoff The Air Force Office of Scientific Research (AFOSR), with additional funding from the National Science Foundation (NSF), recently established a program to enable civilian astronomers to use the 3.6-meter Advanced Electro-Optical System (AEOS) located at the Maui Space Surveillance Site on Mt. Haleakala, Hawaii. Astronomers participating in this program provided credibility and validation of the superiority of the AEOS assets from an objective and knowledgeable vantage point.

Accomplishment Five groups of astronomers from around the country made observations using the AEOS in the last 12 months. Most of these astronomers have experience with adaptive optics systems at other observatories and share that experience with the Air Force (AF) research staff. This scientific collaboration improved the performance of the AEOS telescope with corresponding increases in the quality of data provided to the AF operational mission.



The AFOSR and NSF designed the AEOS facility to allow unclassified, academic observers to occupy AEOS at the same time as observers working classified programs with no relaxation of classified requirements. The data taken by these scientists is of extremely high quality and very useful to their programs.

Background The NSF took the lead role in releasing a call for proposals as well as forming a peer review panel to choose proposals to fund. During the first year of the program, the NSF received 25 proposals and funded 5. Since the program began in 2000, the NSF funded a total of 14 proposals. Scientists from the first five funded programs made observations at AEOS.

Shortly after initiating the astronomy program, the AFOSR and NSF established a similar program in atmospherics. This program is currently in the process of setting up equipment for a measurement campaign that will last several years.

Advanced Electro-Optical System is Operational

Payoff The state-of-the-art capabilities of the Advanced Electro-Optical System (AEOS), located at the Maui Space Surveillance Site on Mt. Haleakala, Hawaii, are providing significant payoffs to a broad range of user communities. The high-resolution images from the adaptive optics/visible imager system provide resolved satellites for which resolved images were not previously available. The Directed Energy Directorate routinely uses a long wavelength infrared (LWIR) imager to satisfy the highest priority tasking of objects from the Air Force Space Command (AFSPC). The directorate also provided support for missile shots, and other government agencies are expressing interest in using AEOS to support their programs. Astronomers and atmospheric scientists will continue using of AEOS in the future.

Accomplishment The directorate accomplished testing of the complete integrated AEOS, which became operational in August 2000. The directorate operates the AEOS seven days per week to provide state-of-the-art images and signature data on space objects. This capability, together with the capabilities of the other telescopes and sensors of the Maui Space Surveillance Site, now provides 24 hours per day, 7 days per week observational capability of space objects. Visiting astronomers use the AEOS dual-use capability extensively for their experiments.

International Space Station with Space Shuttle attached

Hubble Space Telescope

Background The development of AEOS began in 1991. The directorate developed three state-of-the-art sensors to collect data with the 3.67-meter aperture telescope. Those sensors include a four-channel radiometer, an LWIR imaging sensor, and a visible imaging sensor coupled with a state-of-the-art adaptive optics system.

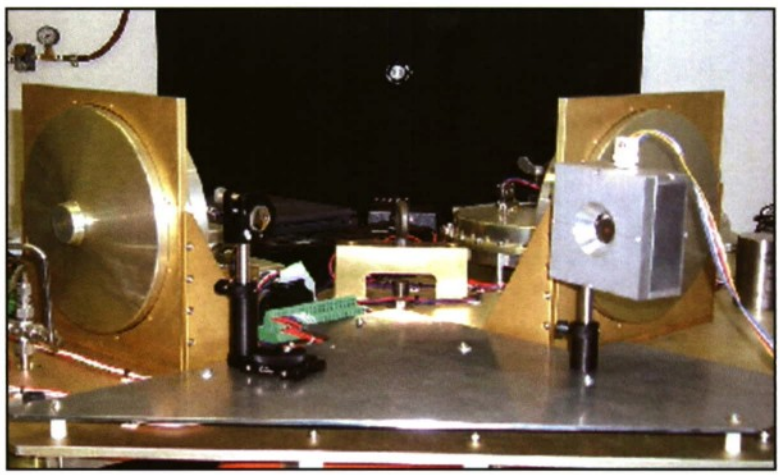
The directorate designed the AEOS as a user-friendly, dual-use facility to provide support to the Air Force space surveillance mission as well as to other government agencies, academia, and astronomy communities. The AFSPC originally operated AEOS; however in 1998, AFSPC transferred the responsibility for its operation to AFRL.

Relay Mirror Technology Development

Payoff A relay mirror system has several potential military applications for directed energy. It is the critical element in many future Air Force space-related missions. It will provide a global infrastructure for force projection, information dominance, and force enhancement missions. Identifying and integrating the necessary control systems for the opto-mechanical control of satellites is a crucial step in technological advancement for relay mirrors and other space-based optical platforms. The Directed Energy Directorate and Naval Postgraduate School (NPS) worked together to enable future systems with large optics and the necessary controls to meet the stringent requirements of future space-based tactical weapons systems.

Accomplishment The directorate and NPS teamed together to create a robust demonstration coupling optical control and attitude control of a satellite. Recently, directorate personnel built the optical system and set it up at the NPS facility.

The NPS built a satellite control test bed with three reaction wheels to simulate attitude control in space. In 2001, the team demonstrated beam stability, acquisition, and tracking of a cooperative target on a stable satellite test bed and continued their effort in demonstrating the same beam control while "floating" the satellite test bed.



Background The relay mirror system will require many subsystems and many levels of control. The proposed bifocal design, consisting of two symmetric, optically linked telescopes, poses many challenges for basic satellite dynamics and control. Also stringent requirements exist for slewing and tracking that make satellite control a major challenge for relay mirror development.

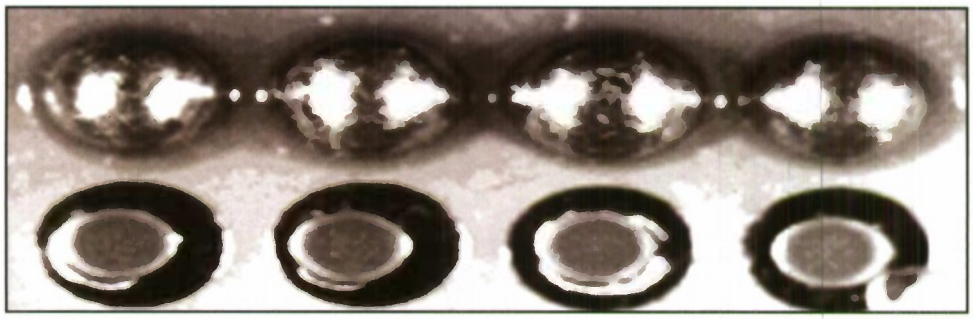
The directorate teamed with the NPS to help resolve some of these technical challenges. The approach is to develop theoretical models of both the attitude control system and the optical control system, demonstrate them separately in the lab, and then integrate them. This control integration is key in tackling momentum and attitude.

Commercializing High-Power Diode Lasers

Payoff The Directed Energy Directorate wanted to leverage its high-power diode laser technology into materials processing applications to help reduce the cost of these devices. Dr. John McKillop of Laser Fare, working with Dr. Chandra Roychoudhuri at the University of Connecticut, and Dr. Efrim Portnoi at the Ioffe Institute in St. Petersburg, Russia, succeeded in developing grating coupled surface emitting lasers (GCSELs) that hold promise as low-cost, high-power laser diodes.

Accomplishment Infinite Photonics, Inc.'s (IPI's) proprietary (patent pending) GCSEL technology improved upon Laser Fare's basic GCSEL design. It uses a sophisticated, yet simple, design that simultaneously delivers higher average power, higher brightness (focusability), and lower cost than conventional high-power diode lasers. GCSELs are useable as signal sources in fiber optic communications, as "pumps" to provide energy for other solid-state lasers, to make printing plates in commercial digital printing, and as low-cost laser sources for materials processing.

IPI demonstrated GCSELs with output powers up to 8 watts (W) and expects to scale this design to at least 10 W. This is at least eight times more powerful and substantially brighter (more focusable) than current devices. These performance and cost advantages will allow GCSELs to dominate key applications in solid-state laser pumping, materials processing, and medicine.



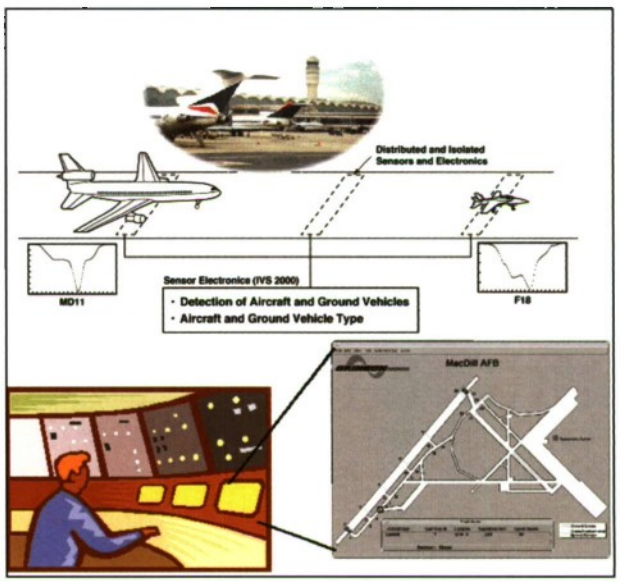
Background Laser Fare is a leading supplier of laser materials processing services to industry and the military. Laser Fare has long believed that high-powered laser diodes are a major force in materials processing, especially in the micromachining and marking areas.

IPI is a start-up company formed specifically to capitalize on unique high-power diode lasers that can readily dominate fast growing markets in materials processing, solid-state laser pumping, medicine, telecommunications, and printing. Based on the strength of its proprietary technology, management team, and unique world-class research and development capabilities, IPI hopes to be the dominant original equipment manufacturer of high-power diode lasers within the next five years.

AFRL Program Enhances Airport Ground Safety

Payoff At a time when airline passengers may face as much danger on the ground as in the air, the Information Directorate demonstrated that 25-year-old highway monitoring technology can enhance ground safety at the nation's airports. The busiest airports around the country are experiencing a dramatic increase in the number of aircraft on runways and taxiways, in addition to a variety of service vehicles around terminals and under airplane wings. The development of extended simple traffic light sensors performing advanced ground vehicle safety protection can solve the congestion problem.

Accomplishment Engineers at the directorate and Orincon Corporation of San Diego, California, demonstrated the use of inductive loop sensors as an affordable and reliable ground surveillance and tracking system for airfields. Orincon's Ground Safety Tracking and Reporting System (GSTARS) test involved a simulation of a potentially disastrous runway collision in which one aircraft pulled into the path of another cleared for takeoff. Sensors in the runway successfully picked up identification, location, speed, and direction information, and then fed the data into a central computer in the air traffic control tower. The GSTARS computer recognized the potential for a collision and warned air traffic controllers.



Previously, engineers used loop sensors to detect, count, and identify vehicles on highways for traffic light control. GSTARS uses this same basic technology to provide detailed information about aircraft and vehicles on runways. GSTARS detects, characterizes, and tracks aircraft, fuel trucks, and other ground vehicles on runways and taxiways in all weather conditions. The system fuses the sensor data together to identify the potential for collisions and alerts the control tower in time to prevent mishaps. The system also enhances security by recognizing unauthorized vehicles. GSTARS can augment existing ground radar by eliminating blind spots and clarifying ambiguous readings that occur through multi-path interference.

Background Orincon combined standard inductive loop sensors with their signal processing and neural network technologies to allow GSTARS to classify a vehicle in one of more than 20 different categories as well as accurately estimate vehicle speed and length. Engineers can install the system for about one-tenth the cost of a current ground radar system, offering additional savings in maintenance.

The system is especially valuable in situations where a controller cannot visibly monitor the runway due to obstructions, poor weather conditions, or darkness. The system can also assist controllers responsible for monitoring activity at "uncontrolled" airstrips that may be several miles away from a control tower.

Multi-Lane Traffic Monitoring Sensor Eases Roadway Safety Concerns

Payoff The Multi-lane Traffic Monitoring Sensor (MTMS), a low-cost, nonintrusive, lane-monitoring sensor that measures and classifies vehicular traffic over multiple-lane roadways, will help eliminate roadway installation safety concerns. This sensor permits portable or permanent setup on the roadway berm without costly construction, maintenance, traffic disruptions, or hazardous situations for highway personnel. It also provides for growth to meet advanced requirements for the Federal Highway Administration and the Ohio Department of Transportation (ODOT). Numerous departments of transportation, including Minnesota, Florida, and Hawaii, are expressing keen interest in this traffic sensor technology.

Accomplishment The MTMS represents a major achievement in traffic engineering through portability, low cost, easy setup, and elimination of hazards to motorists and highway maintenance personnel. Traffic engineers can safely install the remote traffic monitoring sensor on the side of the road without disturbing traffic. This low-cost system collects data and monitors traffic at remote locations. Information Directorate engineers designed and developed this sensor using existing aerospace technologies. MTMS uses dual-beam lasers to detect vehicles under various highway conditions, then processes and stores the signals for later traffic analysis. The unit is portable, self-contained, and nonintrusive to the roadway. Safety to technicians and motorists was a primary design consideration.

Background Current traffic monitoring systems consist of inductive loops, piezo-electric switches, and road tube sensors to record traffic counts, classify vehicle type, and gather speed data. The ODOT maintains approximately 200 permanent induction loop/piezo-electric switch systems and collects approximately 3,750 portable road tube counts per year.

Traffic engineers recommend installing permanent sensors while constructing a highway; however, they can install the sensors later at a much greater expense. ODOT workers replace the monitoring sensors at a permanent installation site at additional cost when making major road repairs.

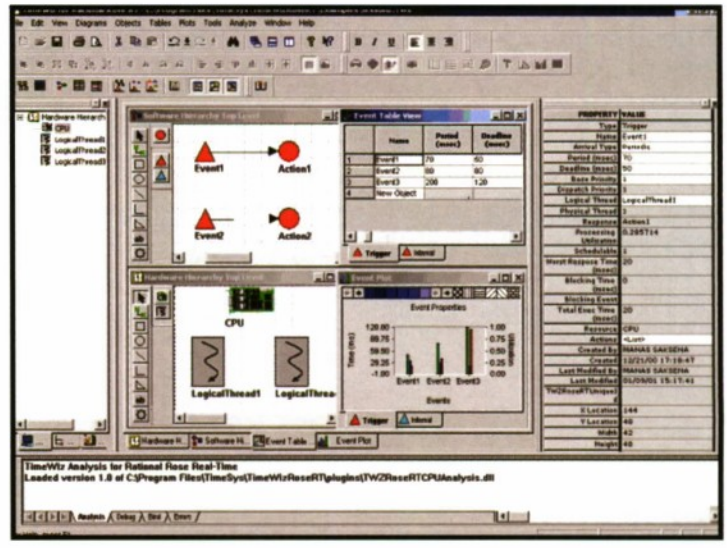
ODOT expressed a need for a low-cost, nonintrusive traffic monitoring sensor that is safe to install. The essential requirements included classifying the vehicle type by lane, monitoring one to four lanes of traffic simultaneously, and measuring vehicle velocity within ± 1%. Additional requirements included packaging each system as a self-contained portable unit that can be erected in less than 30 minutes, operating over a continuous 48-hour cycle, and exhibiting the capability to communicate electronically from remote sites. This sensor also meets the requirements of interfacing with existing traffic monitoring system boxes for data processing and occlusion prevention, which is the simultaneous tripping of the laser beam or the blocking of one vehicle tire by the tire of another vehicle.

Temporal Analysis Capability Enhances Real-Time Unified Modeling Language Tool

Payoff Working in conjunction with Information Directorate researchers under a Ballistic Missile Defense Organization-funded Small Business Innovation Research Phase II contract and through other private funding, TimeSys Corporation developed a commercial product called TimeWiz® for Rational Rose Real-Time. The product provides a complete solution for developing timing-sensitive embedded systems and fully integrates unified modeling language (UML)-based modeling, automatic code generation, and global timing analysis to improve software development.

Accomplishment This research commercialized a valuable combination of UML-based design and time-sensitive analysis capabilities supporting rate monotonic analysis (RMA) within UML models with an underlying event-driven execution paradigm. RMA is a collection of quantitative methods and algorithms that allows engineers to specify, understand, analyze, and predict the timing behavior of real-time software systems, thus improving their dependability and development.

Background A TimeWiz design/analysis model consists of models of resource architecture, software architecture, and a mapping of software architecture elements to the resources. The tool is useable in the early stages of architecture analysis to model the real-time software architecture of a system by focusing only on aspects relevant for performance modeling.



During later stages when an engineer builds a model of software architecture in Rational Rose Real-Time, engineers can automatically import it into TimeWiz. Users can specify the timing requirements and assumptions for analysis purposes when using this software's architecture modeling.

By changing various properties, users can also perform "what-if" analyses. The synthesis engine of the tool computes scheduling attributes (priorities) for elements in the design model in order to meet the response time requirements. The synthesis engine can also optimize the mapping from logical threads to physical threads.

TimeSys Corporation engineers employed user feedback from developers like Lockheed Martin Aeronautics Company in the development of this integrated computer aided software engineering (CASE) capability. The resulting package represents a significant advancement as it has commercialized laborsaving CASE capabilities that address key Department of Defense needs. Lockheed Martin plans to employ integrated UML/RMA CASE tools on major avionics software development programs in the near future.

Prototype Digital Watermarking Camera and Software Delivered

Payoff Today users can easily copy digital images even though this copying may violate copyright laws. To help eliminate this problem and provide hidden value-added information, a prototype digital watermarking camera and software were developed and demonstrated. Copyright violators will no longer be able to copy images unchecked. The military can instantly detect any image tampering and trace ownership and distribution activities.

Accomplishment The Information Directorate recently took delivery of a digital watermarking camera, a product of a Dual Use Science and Technology effort with the Eastman Kodak Company of Rochester, New York, and the State University of New York (SUNY) Binghamton in Binghamton, New York. The watermarking camera provides the first prototype of a camera that embeds usable information in invisible watermarks.

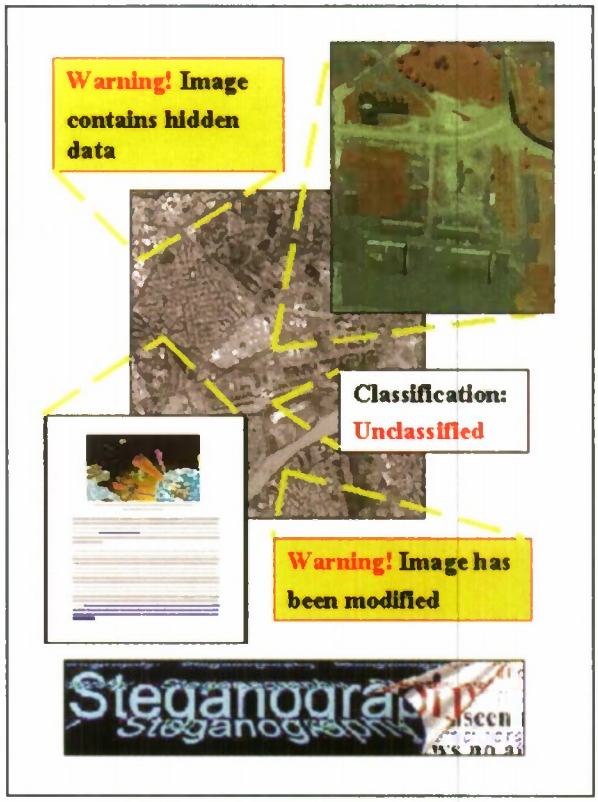
This technology could logically accomplish image marking for source and content authentication (e.g., embedding information on an image's photographer, camera, location, date, and so forth). Kodak's robust watermarking scored the highest benchmark rating achieved to date.

Background The use of steganography for innovative image packaging and access to image products introduces a new paradigm to the imaging marketplace. An image can now contain value-added information throughout its life. Another technological breakthrough by SUNY Binghamton was the development of invertible data embedding. Invertible data embedding opens brand new application areas. This technology eliminates image embedding artifacts after extraction of the hidden data.

Secure digital cameras can provide a wide-range of benefits to both the military and civilian sectors. Benefits include verifying image integrity, embedding a photographer's and/or a camera's signature, automating image dissemination and distribution, enabling covert communication, and providing innovative image product packaging.

Eastman Kodak developed demonstrations for postage stamp and identification card watermarking. Law enforcement officials could develop machine-readable and verifiable driver's licenses. They could also authenticate that images taken at a crime scene were not altered and are the same as those shown in the courtroom.

Eastman Kodak developed demonstrations for restricting imagery access using secret software keys and accessing full resolution images using watermarked thumbnail images. Applications, such as medical and law enforcement imaging, and defense applications, which permit no image degradation, may benefit from invertible embedding technology. With this new technology, users can extract hidden information from within the image as it restores the image to its original pure or pristine quality.



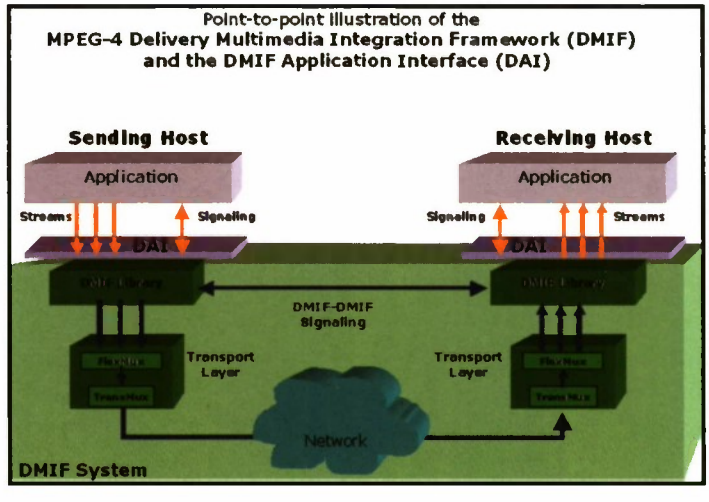
AFRL Installs MPEG-4 Delivery Multimedia Integration Framework

Payoff Software programmers developing multimedia applications that rely on network transport can now use the Moving Picture Experts Group (MPEG)-4 Delivery Multimedia Integration Framework (DMIF) application interface to handle sessions and multiple channels within those sessions. They can also use DMIF to send and receive audio, video, and data with varying quality of service requirements over the channels.

The transport-independent delivery services provided to the application by the DMIF system insulates the applications from network-specific details. This will provide new or modified applications with alternative transport technologies meeting the quality of service demands of interactive multimedia content and will extend their life cycles in spite of the continuing evolution of commercial and military networking technologies.

Accomplishment Through a Cooperative Research and Development Agreement (CRADA) with Xbind, Inc., the Information Directorate's Distributed Information Systems Branch installed the MPEG-4 DMIF system. The test bed provides an experimental platform for the development of multimedia applications using the DMIF application interface. The DMIF system currently provides transport services with varying quality of service requirements to multimedia applications over Internet Protocol and Asynchronous Transfer Mode (ATM) infrastructures.

Background In 1995, the directorate initiated a research effort with Columbia University entitled ATM Management and Control Application Programming Interfaces (APIs). Columbia University researchers applied distributed object-computing technology to the network control software and provided generic APIs through which multimedia applications could dynamically influence the network state in a controlled manner.



Common Object Request Broker Architecture middleware applied a level of abstraction between the distributed computing applications and the network systems in such a way that the applications could request generic services without requiring specific knowledge of the underlying network technology. After successfully demonstrating the concepts, Columbia University's principal investigator established Xbind, Inc. to develop prototypes into commercial products. The CRADA allows the directorate to evaluate Xbind's products against military requirements and keep abreast of the technology.

AFRL Enhances Precision Document Retrieval and Electronic Mail Surveillance

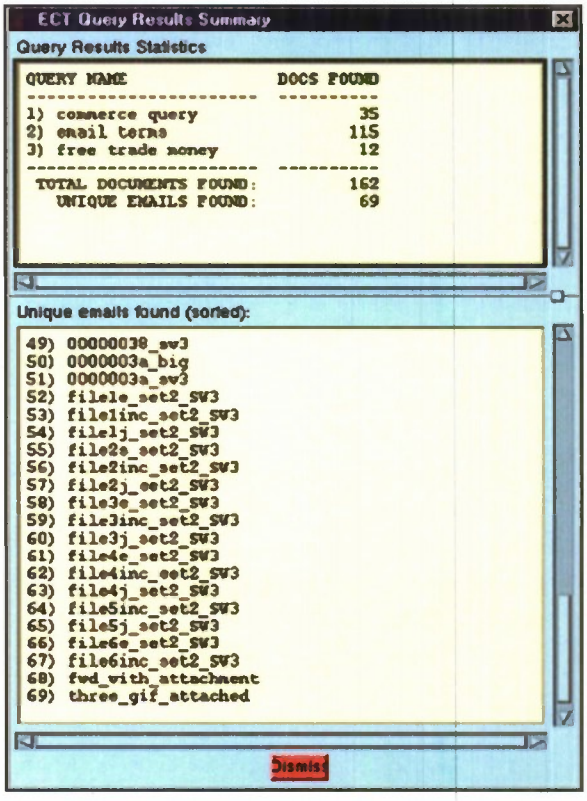
Payoff As military organizations continue to collect and store increasing amounts of textual documents electronically, users need automated tools to facilitate timely retrievals with precision. The Information Directorate in collaboration with the National Air Intelligence Center (NAIC) at Wright-Patterson AFB, Ohio, developed the Document Content Analysis and Retrieval System (DCARS).

Accomplishment DCARS permits users to retrieve text documents with speed and increased precision. It uses a state-of-the-art search engine that includes several dictionaries and thesauri.

The directorate's Global Information Base Branch managed the contract through which tools were developed to convert military thesauri and acronym lists for easy integration into DCARS to increase recall capability. Although DCARS was only in a test environment at NAIC, it served as the basis for a Web interface to NAIC's information system, PORTAL, and is known as WebPORTAL. Customers are enthusiastic about such innovations as the histograms, which serve as a low-level analytic tool.

DCARS provides full text document search and retrieval along with natural language and Boolean searches. The directorate also developed the Electronic Mail Content Analysis and Retrieval System (EMCARS) to catch inadvertent and intentional release of sensitive information.

EMCARS is a unique capability that allows security officers to view e-mail attachments. It automates the electronic mail security-monitoring task, performs precision detection and flagging of suspect text messages, handles attachments and enhances rapid drill down, and limits viewing to suspect text messages.



Background Over a period of years, directorate personnel worked with NAIC and the contractors to make a number of improvements to DCARS. WebPORTAL became the primary access point for external customers to access the various libraries or data types at NAIC. Other DCARS and WebDCARS customers include the National Imagery & Mapping Agency, Sandia Laboratory, Joint Command and Control Warfare Center, Air Intelligence Command, and the 67th Operations Support Squadron at Kelly AFB, Texas.

Early Warning System Developed to Detect Wire Chafing

Payoff Better monitoring of aviation wire systems may keep aging commercial and military aircraft safer for the millions of passengers and crew who fly daily. Damaged wiring poses a serious threat to public health and safety and may result in smoke, fire, or failure of essential functions.

Accomplishment Killdeer Mountain Manufacturing (KMM) of Killdeer, North Dakota, the Montana State University Tech-Link Center (a technology transfer organization) of Bozeman, Montana, and the Information Directorate, teamed up to refine technology that detects damaged wiring in aircraft before it creates a hazard. Aircraft structures contain many miles of electrical wiring with the potential to become dangerously worn and frayed from years of vibration and rubbing against other aircraft parts.

Wire chafing may cause a short circuit in an aircraft's electrical system or spark a fire, both potential sources of disaster. Finding damaged wiring is a difficult task. A Boeing 747, for example, has over 150 miles of wiring, much of it located in inaccessible areas of the aircraft.

This early warning system could augment regular aircraft inspections and vastly improve aircraft safety. It could detect and locate areas where wire chafing is just beginning, long before the electrical insulation has worn off and damage occurs.

KMM developed several sensing technology embodiments, which will be tested and refined under actual operating conditions. This technology also has the potential for detecting early wear in non-wiring components such as hydraulic lines and fuel lines in airborne and surface vehicles.

Background The National Science and Technology Council issued a review on wire system safety last year, concluding that wire system safety is an important public health and safety issue that transcends government agencies. Wire chafing may figure prominently in a growing number of malfunctions.

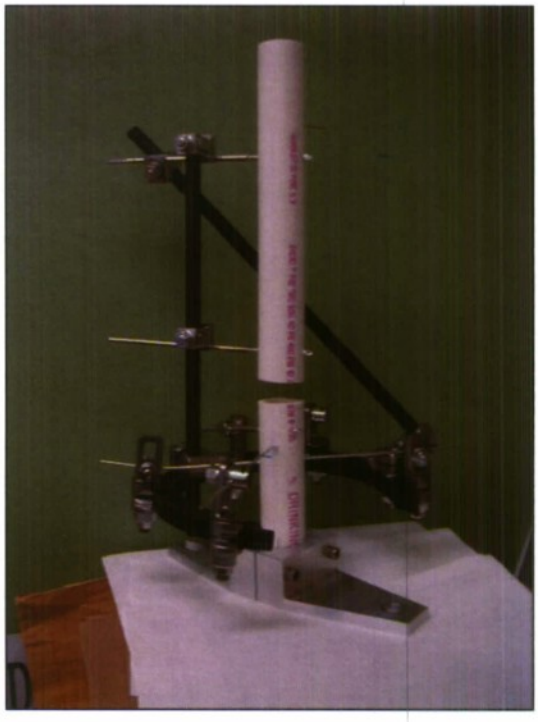
The National Aeronautics and Space Administration's venerable Space Shuttle suffered wire chafing problems. An electrical short caused the loss of two main engine components during the launch of the Shuttle Columbia.

Wire chafing accounts for 37% of wire system failures in reported military aircraft hazardous incidents, while short circuits and unspecified failures account for another 24%, for a total of 61% attributed to wire chafing. Killdeer plans to integrate the directorate's technology into its wire harness assemblies to create a wire-chafing detector that is poised to become part of an important safety system for our nation's commercial and military aircraft.

Scientists Gather Test Data for Promising Bone Reset Technology

Payoff Better medical treatment for critical bone injuries not only benefits soldiers, but the public in general. A device, referred to as an external fixator, relieves the inconvenience and unfavorable side effects of an inaccurate fracture reduction. The accuracy of the performance test data demonstrates the capabilities of the Materials and Manufacturing Directorate's Materials Test and Evaluation Team who conducted the test.

Accomplishment In-house testing conducted at the directorate advances the development of a new medical device that stabilizes and orients broken bones. The Wright State University (WSU) School of Medicine, Department of Orthopedics at Miami Valley Hospital in Dayton, Ohio, designed and tested the device, which examines promising technology to improve the care of soldiers injured in battle and the general populace. As a result of this highly evolved method of treatment, recipients may recover more fully.



Background Soldiers in battle experience bullet and shrapnel wounds, which sometimes result in bone fragments that are either lost or cannot be pieced together, making precise realignment of the bones extremely difficult if not impossible. Attempting to realign the bones using a cast, plates, and screws can also prove inadequate. The general populace also suffers when broken bones cannot be properly aligned while mending.

Another unfortunate outcome, for soldier and citizen alike, is permanent reduced mobility, which can sometimes lead to early mortality. Directorate scientists and engineers provided in-house laboratory support to the WSU School of Medicine, Department of Orthopedics, at Miami Valley Hospital, and evaluated variations of a device developed to separate and precisely orient broken bones.

The external fixator is a series of wires, screws, and braces that orient fractured bones to heal in their original shape. The bones grow best with repeated and controlled axial loading with the avoidance of any side-to-side sliding at the fracture, which can keep the bones from unifying. The ideal external fixator allows limited axial flexing but not side-to-side shearing motion or rotational torsion.

The development of the final fixator configuration required evaluation and testing on simulated bones of initial deflections and the impact of loosening screws as well as other critical procedures. The Materials Test and Evaluation Team's critical expertise can design, set up, and perform such a unique set of tests.

The Wright Technology Network, an organization funded in-part by the State of Ohio and established to promote technology transfer to the private sector, assisted WSU in arranging directorate testing on the fixators. WSU is working on additional testing of these devices, which could lead to further design improvements and technical refinements.

In-House Expertise in Nanotechnology Boosts Development of Consumer Products

Payoff Polymer-matrix nanocomposites could replace composite and polymer materials currently used to design and manufacture critical substructures in aircraft and space vehicles, fuel-line brackets, combustion chambers, and cryogenic storage containers, resulting in substantial weight and cost savings. Transfer of this new technology to private industry led to a licensing agreement between Triton Systems, Inc. and a major athletic shoe company for the production of helium-filled pouches for athletic shoes. Scientists are studying nanocomposites for a number of other innovative commercial applications.

Accomplishment Extensive in-house research and development (R&D) efforts at the Materials and Manufacturing Directorate, together with R&D efforts at Triton Systems, Inc., reduced the weight and cost of aerospace composites and polymer structural materials used on air and space vehicle systems. This technology uses nanocomposites with nano-reinforcements 10,000 times smaller than the diameter of a human hair to manufacture components vital to both military and commercial systems. This technology will also benefit commercial industry through the successful design and development of dynamic new consumer products.

Background The increased performance needs of future aircraft and space vehicle systems require high-use temperature, lightweight, polymeric materials. Triton Systems, Inc., with directorate support under the Small Business Innovation Research program, developed a new generation of polymer-matrix nanocomposites based on the molecular-level dispersion of highly anisotropic, inorganic, nano-scale rods or plates. This polymer-matrix nanocomposite is similar to mica-type layered silicates in a thermoplastic polymeric resin.

Polymer nanocomposites exhibit significant increases in thermal stability and over a 10-fold improvement in barrier to oxygen and water vapor compared to neat polymer resins. These property improvements extend the number of potentially useful environments of polymeric material. Additionally, nano-scale inorganic particles comprise less than 10% of the weight of the nanocomposites, in comparison to conventional filled-polymer systems where inorganic materials comprise more than 30% of the weight. The overall weight of the nanocomposite is less than that of conventional composites while enabling the same important property enhancements.

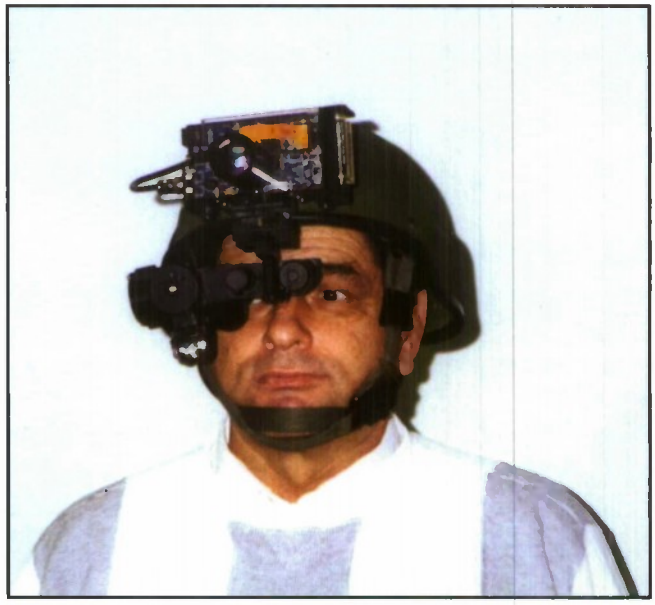
Dr. Richard Vaia and other research professionals in the directorate's Polymer Branch transferred these material technology advancements to the commercial sector. The impact of this technology transfer may be international in scope since shoe manufacturers distribute these products to more than 90 countries worldwide.

The athletic shoe uses helium-filled capsules to provide greater cushioning and shock absorption over conventional shoes. This technology enabled shoe manufacturers to design a lower heel, placing the foot 25% closer to the ground than other athletic shoes. Since helium is difficult to encapsulate in plastic, Triton Systems used nano-scale platelets in the capsules to prevent the gas from escaping.

Helmet-Mounted Infrared Imaging and Communications System Aids Firefighters

Payoff The Advanced Rescue Vision System (ARVS) provides fire departments with multiple capabilities. Firefighters can use the new lightweight, hands-free imaging and communications system to quickly locate victims in smoke-filled buildings or aircraft. Fire commanders can use the system to more effectively conduct command and control operations on both the exteriors and interiors of burning structures. ARVS speeds up the rescue process, enhances communications between fire commanders and firefighters, and for the first time, provides firefighters with an opportunity to view the actual fire condition inside burning buildings or large-frame aircraft. In a decisive way, this new technology takes the guesswork out of nighttime operations.

Accomplishment The Materials and Manufacturing Directorate, working with Zybron, Inc. of Beavercreek, Ohio, developed a helmet-mounted infrared imaging and communications system for firefighters under a Phase I and II Small Business Innovation Research contract. The ARVS is a major leap forward in firefighter-capable infrared imaging devices. Designed exclusively for firefighters, the system's enhanced video and audio capabilities provide clear images and uninterrupted communications through dense smoke often encountered in burning buildings or aircraft. Zybron expects a decrease in the cost of this technology from $25,000 per unit to under $5,000, enabling fire departments to buy more units and improve lifesaving capabilities.



Background ARVS is a helmet-mounted, state-of-the-art, long wavelength infrared (LWIR) imaging and communications system that helps firefighters locate victims, entrapped individuals, and objects or obstructions through dense smoke, fog, and dust. These conditions typically restrict or severely limit the effectiveness of fire-fighting tactics in large smoke-filled structures and during nighttime warfighting situations.

ARVS accurately relays video images and audio transmissions to firefighters and fire commanders, who make immediate decisions regarding rescue and operations. The new device detects and displays minute temperature differences as small as .07°C, which enables firefighters to distinguish between combustion, furniture, humans, and obstructions including collapsed ceilings.

Air Force pilots could use this new LWIR system to pinpoint enemy aircraft and ground targets by day or night and in all kinds of weather. ARVS could become an ideal tool for helping medical personnel perform life-saving emergency surgery on the battlefield without the benefit of light. Zybron could transition ARVS to the United States Army, Marines, Border Patrol, Special Forces, and Security Forces at sensitive military sites at home or abroad.

Appliqué Protective Coating Technology Extends Life of Stored F-16 Horizontal Stabilizers

Payoff A 3M Company protective coating, called Appliqué, shields the F-16's composite horizontal stabilizer from ultraviolet light and other forms of damage such as wind and sand erosion. Eliminating the requirement to replace stabilizers due to environmental damage could save the Air Force several hundreds of thousands of dollars. The Navy is also considering the coating to protect the F-18 fighter and other military aircraft stored at the Aerospace Maintenance and Regeneration Center (AMARC).

Accomplishment The Materials and Manufacturing Directorate, in conjunction with the 3M Company, identified and transferred a specially formulated adhesive film to protect composite horizontal stabilizers on F-16 fighter aircraft stored at AMARC. Funded by the Environmental Security Technology Certification program, this transfer of commercial technology to the Air Force effectively demonstrates how the public and private sectors work together to support the nation.

Background AMARC is a joint military service organization that stores, regenerates, and disposes of aircraft and related aerospace equipment. Located at Davis-Monthan AFB, Arizona, the AMARC F-16 fleet allows military units throughout the world to withdraw parts and aircraft when needed.

Situated near Tucson, Arizona, the climate around Davis-Monthan AFB is dry with low humidity and alkaline soil. These conditions allow AMARC to store aircraft for an indefinite period of time with minimum deterioration and corrosion. In addition, the soil is hard, which makes parking the aircraft relatively easy, even without concrete or steel parking ramps.

Despite the advantages offered by a dry, desert environment, AMARC workers must adequately protect composite aircraft components, such as the F-16 horizontal stabilizer, from ultraviolet light as well as sand and wind erosion. Working with the 3M Company, engineers at the Coatings Technology Integration Office at Wright-Patterson AFB, Ohio, identified and helped transition the specially tailored, protective, adhesive film called Appliqué into the AMARC F-16 program.

Appliqué film now protects most F-16 horizontal stabilizers at AMARC, eliminating the cost of replacing components and the need for additional protective coatings, and effectively demonstrating the viability of a new applied technology. The F-16, considered by many to be the most agile fighter aircraft in military service, forms the backbone of the Air Force fighter fleet. The Air Force, the Department of Defense, and the taxpayer will benefit from the long-term preservation of the F-16s stored at AMARC.

Advanced Composites Design Training Aids Aspiring Olympic Athletes

Payoff An Advanced Composites Office (ACO) project enabled one of its newest members to acquire and hone additional computer-aided design (CAD) skills, while transferring Air Force composite processing technology to a non-military application.

Accomplishment Engineers at the Materials and Manufacturing Directorate redesigned the aerodynamic component of an Olympic racing skeleton sled using advanced aerospace composites. This unique composites design training effort may carry an Air Force officer to victory in the 2002 Winter Olympics.

Engineers developed the redesign effort to provide valuable hands-on CAD, three-dimensional (3-D) modeling experience for a new member of the ACO. The redesign also proves and advances several composite material concepts that have application to aerospace vehicles.

Background The skeleton sled is comprised of a steel chassis and steel runners. The athlete lies face down on top of the sled in a head-first position. The bottom of the sled, or pod, is comprised of a steel (sometimes fiberglass) sheet affixed to the underside of the chassis to provide aerodynamic benefits, much like the underside of a Formula One racing car.

ACO engineers used a hand-built model of the pod to generate a 3-D representation, placed the pod into the CAD program, and changed the part's shape. To optimize the contour for airflow, ACO engineers made two different part designs, each conforming to the standard two-feet wide by three-feet long dimensions.

Next, the engineers downloaded the 3-D model to a five-axis router and cut a wooden master. Then, they used the master to make a fiberglass female mold. With this mold, engineers produced a hand lay-up part using the same graphite epoxy employed on the C-17 transport aircraft.

Since strength is a critical factor in skeleton sleds, the engineers used an autoclave to optimize curing of the sled pod. The skeleton sled has no steering, braking, or propulsion capability. It moves only by the pushing force provided by the athlete at the beginning of the race and the force of gravity as it winds through the course sometimes at speeds in excess of 80 mph.

Awards and Recognition

Five Inducted as AFRL Fellows

Payoff Recently selected AFRL Fellows include Dr. Gordon Hager, Directed Energy Directorate; Mr. Dean F. Kocian, Human Effectiveness Directorate; Dr. Ruth Pachter, Materials and Manufacturing Directorate; Dr. Stephan D. Price, Space Vehicles Directorate; and Dr. Harold Weinstock, Air Force Office of Scientific Research.

Individuals appointed as AFRL Fellows lead and take part in special activities that enhance the laboratory's image. These scientific leaders represent the lab in significant endeavors in the national and scientific engineering communities and advise senior managers on substantial issues as needed.

Accomplishment Dr. Hager developed a pulsed version of the chemical oxygen/iodine laser as a potential candidate for Airborne Laser illuminator laser and demonstrated the first all-gas phase iodine laser.

Mr. Kocian is the Air Force champion of helmet-mounted tracker/display technology that enables pilots to aim weapons using the natural abilities of their heads and eyes to track targets while displaying critical flight and targeting data directly on the visor.

Dr. Pachter's research and development has significantly advanced laser eye protection, and space and sensor protection applications.

Dr. Price has been a leader in implementing state-of-the-art sensor and component technology, and in the design and conduct of space-based experiments.

Dr. Weinstock oversees work involving superconductivity in magnetic materials and nanoelectronics. He authored 20 publications, edited 5 books, and has 2 patents on applications of superconducting magnetometry to nondestructive evaluation.

Background Military and civilian scientists and engineers, comprising about 55% of AFRL's workforce, are eligible for selection as an AFRL Fellow. Eligible participants must be assigned to AFRL for the past three consecutive years and have at least seven years of active federal service. Participants must perform the recognized work at the laboratory or one of its predecessors.

Appointment as an AFRL Fellow recognizes ideas, leadership, and motivation toward high achievement in direct support of the warfighter. Fellow selection recognizes AFRL's efforts in support of Air Force operational requirements and significantly enhances the laboratory's reputation as a world leader in research and development.

Major Tim Lawrence Chosen as One of Ten Outstanding Young Americans for 2000

Payoff Recognized as one of the Ten Outstanding Young Americans for 2000, Major Tim Lawrence of the Air Force Office of Scientific Research, stands out as an exceptional example of the quality of active duty personnel engaged in basic research in support of the Air Force mission.

Accomplishment The US Junior Chamber of Commerce named Maj Lawrence as one of the Ten Outstanding Young Americans for 2000 during a ceremony at the Renaissance Hotel in Washington, D.C. Maj Lawrence shares this honor with 600 young people previously selected by the Junior Chamber of Commerce as the best, brightest, and most inspirational leaders that America has to offer. Former notables include President John Kennedy, Howard Hughes, Orson Wells, Elvis Presley, and Christopher Reeve. The Junior Chamber International also nominated Maj Lawrence as one of Ten Outstanding Young Persons of the World for 2001.

Background In 1988, Maj Lawrence graduated from the United States Air Force Academy (USAFA) with a degree in mathematical sciences and earned a master's degree in nuclear engineering at the Massachusetts Institute of Technology in 1993. As a follow-up, he won an award from the Department of Energy's Brookhaven National Laboratory to conduct research critical in developing propulsion systems for future National Aeronautics and Space Administration interplanetary missions.

Maj Lawrence next served as an instructor at USAFA in the Department of Astronautical Engineering. In 1998, Maj Lawrence completed his PhD from the University of Surrey, United Kingdom.

In December 2000, Maj Lawrence received the Thomas Hawksley Gold Medal from the Institution of Mechanical Engineers for a research paper entitled "Research into Resistojet Rockets for Small Satellite Application."

At the European Office of Aerospace Research and Development, the London detachment of the Air Force Office of Scientific Research, Maj Lawrence's responsibilities included surveying the achievements in space technology across Europe, the former Soviet Union, the Middle East, and Africa. He started more than 40 cooperative space research projects between the US and European space nations.

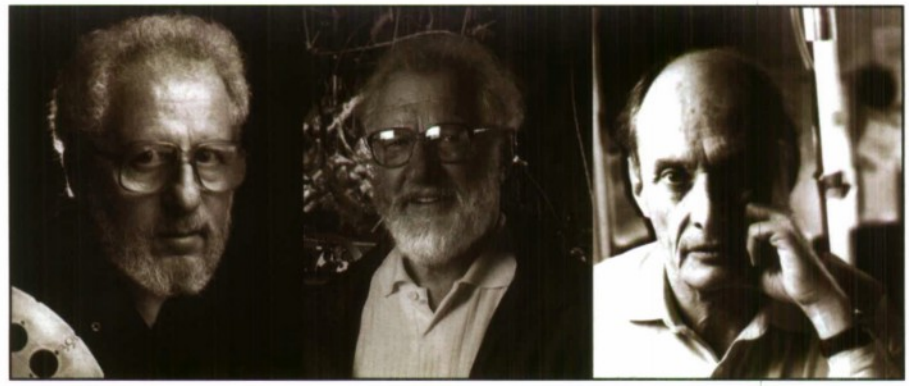
To his further credit, the Department of Defense (DoD) selected Maj Lawrence as the sole DoD member on the National Aeronautics and Space Administration's Nuclear Thermal Propulsion Technical committee. In 1998, the International Astronautics Federation recognized Maj Lawrence for an outstanding propulsion paper. Also, during his assignment in Europe, Maj Lawrence took advantage of his location and became the first active-duty Air Force member to swim the English Channel in September 1999.

AFOSR Logs Three New Nobel Laureates for 2000 Awards

Payoff The Nobel Prize selection committee awarded three Air Force Office of Scientific Research (AFOSR)-funded researchers the Nobel Prize during a ceremony at the Stockholm Concert Hall in Sweden. This brings the number of Nobel Prize laureates funded by AFOSR to 46. This select group earned worldwide recognition for their research contributions in physics, chemistry, and medicine. Their efforts, individually and collectively, greatly enhance AFOSR's reputation as a world leader in basic research management.

Accomplishment Dr. Alan J. Heeger, University of California Santa Barbara (UCSB), shares the Nobel Prize in chemistry with two other recipients. He helped create a plastic that conducts electricity like a metal. Dr. Herbert Kroemer, a physics professor also at UCSB, shared the Nobel Prize in physics for his pioneering work in laying the foundation for modern information technology. Dr. Paul Greengard of Rockefeller University, received his award in medicine for discoveries of synaptic transmission mechanisms between human nerve cells.

Background Dr. Heeger's innovative research led to one of the greatest chemical discoveries of our time. In the late 1970's, Dr. Heeger, along with two associates, began fundamental research in conductive polymer plastics. The research team found that a thin film of polyacetylene, when oxidized with iodine vapor, exhibited an electrical conductivity increase of a billion times turning an insulator to a conductor.



Today, plastic electronics and plastic lasers are targets of research opportunity supported by all services and agencies of the Department of Defense. AFOSR has continuously funded Dr. Heeger's research in conductive polymers for photonic applications since 1988.

In 1957, Dr. Kroemer was the first to propose the use of thin layers of semiconducting materials, known as heterostructures (novel composites of two or more materials), to develop the heterostructure transistor. In 1963, Drs. Kroemer and Alferoz, working independently, proposed the further use of heterostructures. As a result, they created the heterostructure laser-- an innovation crucial in the development of fiber optic communications.

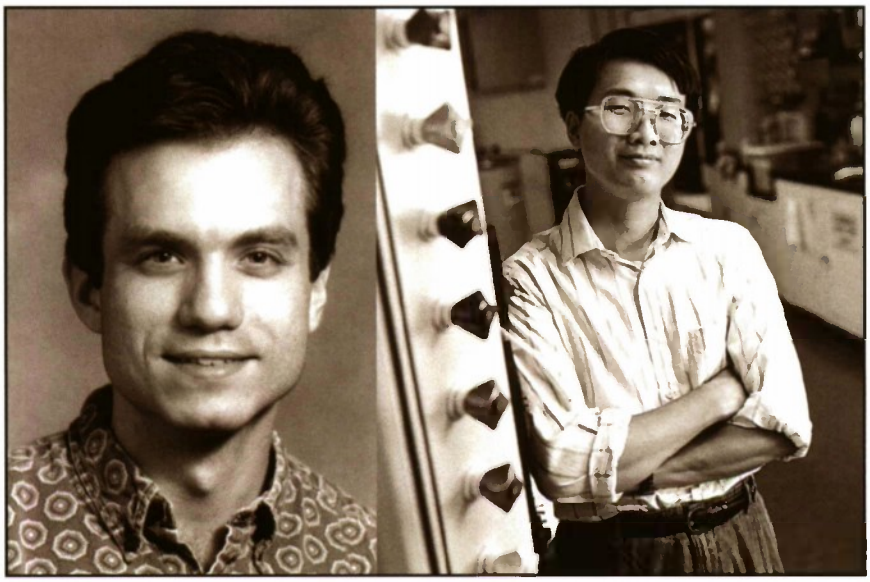
Today, the Air Force and civilian communities use heterostructure technology in radio link satellites, the Internet, mobile phones, and compact disk players. AFOSR supported Dr. Kroemer's continuing work in semiconductors from 1995 to 2000 and continues to support his investigations into the development of unique materials.

Dr. Greengard shared the Nobel Prize for distinction in medicine with two other neuroscientists. Dr. Greengard's research, begun over thirty years ago, demonstrated the means by which chemicals, known as neurotransmitters, carry signals between nerve cells. Dr. Greengard's research provides a solid scientific basis for designing equipment and jobs to match human capabilities and limitations. AFOSR supported Dr. Greengard's research in neurotransmission from 1984 to 1987.

Two AFOSR-Supported Researchers Win Presidential Award

Payoff Dr. John G. Morresett of Cornell University and Dr. SonBinh T. Nguyen of Northwestern University, received the prestigious Presidential Early Career Awards for Scientists and Engineers (PECASE) for the year 2000. The Department of Defense (DoD) recognized these two researchers for their outstanding research and interest in areas ranked as high priority by the DoD that show great relevance for the US Air Force.

Accomplishment Dr. Morrisett conducted his research at Cornell University in the field of software engineering on an Air Force Office of Scientific Research (AFOSR) project managed by Dr. Robert Herklotz, Directorate of Mathematics and Space Sciences. Dr. Morrisett's research focused on the design and implementation of compilers for programming languages with richly expressive-type systems.



Dr. Morrisett's work provides the foundation for software that may one day support very high levels of formally provable security for mobile and transportable code. Additionally, this new approach provides a much higher level of security and code protection than presently available, which supports a wide variety of future military and civilian applications with mobile code. This capability should enable safe deployment of network and computer infrastructures required for a modern battlefield.

The second PECASE winner, Dr. Nguyen, conducted his research at Northwestern University in the field of nano-material synthesis on an AFOSR project managed by Lt Col Paul Trulove, Directorate of Chemistry and Life Sciences. Dr. Nguyen built a world-class materials and catalysis research effort, producing cutting-edge research in the areas of polymers and nano-materials.

Dr. Nguyen's plans include expanding his nano-material synthetic processes to the production of nano-building blocks with unique functionalities. Engineers can then use these new materials for the construction of novel nano- and meso-scale devices.

Background Eight federal departments annually nominate the most meritorious young scientists and engineers who advance science and technology and provide the greatest benefit to participating government agencies. The Presidential Awards emphasize government priority in maintaining US leadership in science by nurturing outstanding scientists and engineers. This award recognizes the finest scientists and engineers who, early in their research careers, show exceptional potential for leadership in the frontiers of scientific knowledge. The award includes a five-year, $500,000 research grant.

Air Vehicles Scientists Receive the Perkins In-House Engineering Award

Payoff Dr. David B. Doman and Dr. Anhtuan Ngo of the Air Vehicles Directorate's Control Theory Optimization Branch, Control Sciences Division, jointly received the Dr. Courtland D. Perkins In-House Engineering Award for their collaborative work on the adaptive reconfigurable control (ARC) law for the X-33. The ARC-X33 design increased the efficiency of the control system computational needs, requiring only a 25% increase in central processing unit usage over baseline. National Aeronautics and Space Administration (NASA) engineers found the X-33 control law, designed by Dr. Doman and Dr. Ngo, to be a highly promising candidate for transition to the next generation reusable launch vehicle (RLV).

Accomplishment At the invitation from NASA-Marshall program managers, Drs. Doman and Ngo developed one of the advanced control law designs for the sub-orbital X-33, an unmanned RLV designed to demonstrate advanced technologies that will dramatically increase launch vehicle reliability and affordability. The methodology chosen by Drs. Doman and Ngo addressed both Air Force and NASA objectives for operability and safety.

Background The directorate established the Dr. Perkins In-House Engineering Award in 1990 to honor engineers and scientists making the most significant in-house contributions to aerospace technology. The award seeks to perpetuate the spirit of excellence and innovation exemplified by Dr. Courtland D. Perkins throughout his distinguished career with the Air Force and as president of the National Academy of Engineering.

Dr. Philip Beran Receives the General Benjamin D. Foulois Award

Payoff The Air Vehicles Directorate recently awarded the General Benjamin D. Foulois Award to Dr. Philip Beran, Structural Design and Development Branch, Structures Division, for his pioneering research on high-fidelity design analysis for nonlinear aeroelastic systems. Dr. Beran successfully applied his technique to a variety of physical systems including a chemical reactor. His reduced-order modeling (ROM) aerodynamic analysis shows a 100-fold efficiency improvement for the prediction of nonlinear, quasistatic solutions and a 10-fold improvement in the prediction of unsteady solutions.

Accomplishment Dr. Beran developed a fast, new approach for modeling nonlinear, aeroelastic systems, enabling researchers to explore the stability of new vehicle concepts. By creating a technology that captures physics-based, fluid-structure interactions in air vehicle systems at the design level, Dr. Beran eliminates potentially destructive aeroelastic behaviors prior to development.

Dr. Beran successfully demonstrated that researchers could compute fundamentally nonlinear behaviors with a very small number of degrees of freedom, leading to significant improvements in modeling efficiency. Dr. Beran also significantly contributed to the field of ROM by developing a multi-purpose algorithm, based on proper orthogonal decomposition, capable of reducing the size of discrete systems in a fully nonlinear fashion.

Background Benjamin Foulois enlisted in the Army in 1898 and, until his retirement as a Major General in 1935, contributed greatly to the Army and later to the Air Corps including his participation in the 1909 trials of the Wright Flyer No.1. He also developed the first airplane radio receiver in 1911.

The directorate established the General Benjamin D. Foulois Award in 1965 in order to perpetuate this pioneering aviator's exploratory spirit. This award honors directorate engineers and scientists who made the most significant contributions to aerospace technology during the previous year.

Power by Wire Program Wins Prestigious Award

Payoff Studies show that integrated subsystems (e.g., electric flight control actuation) are more reliable, maintainable, and affordable and can result in a 13% reduction in life-cycle costs. Integrated subsystems can further reduce gross takeoff weight by as much as 6%, improving range and maneuverability, and thereby improving safety and combat survivability.

Accomplishment The Power by Wire program, a joint Air Force/Navy program, received *Flight International* magazine's 2001 Aerospace Industry Award for Engineering, Maintenance and Modification at the Paris Air Show. The Joint Strike Fighter (JSF)/Integrated Subsystems Technology program funds the Power by Wire program and Lockheed Martin Aeronautics Company leads the program.

The flight test demonstrated flight control technology designed to reduce life-cycle costs and improve performance, safety, and survivability. It was also the first flight test of a manned aircraft of any type to fly with a totally electric actuation system. The demonstration capped off years of research and technology and illustrated that electric actuation can successfully be reduced to a low-risk reality.

Background The Power by Wire program's objective is to reduce the cost and technology risks of selected high-payoff technology candidates for the JSF program. Comparisons with competing technologies demonstrate that power by wire is more cost effective, and demonstrations prove the technology will work.

The Air Vehicles Directorate's nearly flawless flight test program consisted of seven flights conducted at the Lockheed Martin Aeronautics' facilities in Fort Worth, Texas. The directorate achieved all flight test objectives including testing at 500 knots, low altitude, and Mach 1.3 at 30,000 feet.

Directorate researchers modified the aircraft, the Advanced Fighter Technology Integration F-16, with a new power generation and distribution system to provide 270-volts direct current electrical power, rather than the standard hydraulic power generation system in use. Flying with no hydraulic or manual backup power system was a first in aviation for manned aircraft.

Directed Energy Directorate Donates Refurbished Computers to Local Schools

Payoff A new generation of technically literate youth is important not only to the Air Force, but also to the nation. Through the Air Force Research Laboratory Technology Equipment for Kids project, the Directed Energy and Space Vehicles Directorates at Kirtland AFB, New Mexico are doing their part to assure the United States (US) retains the advantages in technology it enjoys today.

Accomplishment Since 1996, the Directed Energy and Space Vehicles Directorates have had an Education Partnership Agreement with New Mexico Technet, Inc. Under this agreement, the directorates transfer surplus computer equipment deemed educationally useful to New Mexico Technet, Inc. Technet personnel examine, upgrade, and distribute these computers and other computers donated from other government and private industry, to primary and secondary schools for use in technology education.

Recently, New Mexico Technet, Inc. donated its 20,000th computer to the Santa Fe Indian School. The New Mexico Legislature appropriated over $2M to New Mexico Technet, Inc. for the refurbishment of technology equipment for kids such as that transferred by the directorates. In addition, Intel® donated over 10,000 computer processors for use in upgrading computer equipment. To date, the directorates have donated personal computers, monitors, laptop computers, and printers worth over $3M.

Background Educating the next generation of scientists and engineers is critical to maintain US technological strength through the coming decades. Such training begins in elementary and secondary schools. Through the Technology Equipment for Kids project, AFRL directorates hope to spur an interest in math, science, and technology among young, and sometimes disadvantaged, students by supplying older-model computers to their schools. Under presidential authority of the Education Partnership Act, laboratory directors may supply research equipment to educational institutions or nonprofit organizations for the conduct of technical and scientific education and research.

Raven System Certified as Space Surveillance Network Sensor

Payoff The Directed Energy Directorate's Raven Team achieved monumental success in defining requirements, designing a low-cost operational telescope system based on off-the-shelf components, and demonstrating that such a system could satisfy a substantial portion of the United States space surveillance metrics requirement. The Raven system significantly improved the accuracy of metric data sent to the Air Force Space Command (AFSPC), while simultaneously increasing the efficiency of the Maui Space Surveillance System (MSSS).

Accomplishment The Raven Team demonstrated the culmination of an effort to field and certify an autonomous telescope that provides metric data to AFSPC. The team installed a Raven telescope on the roof of the MSSS building, then obtained certification of the Raven system by AFSPC.

The Raven system now conducts all autonomous metric tracking at the site and is a certified sensor of the Space Surveillance Network. For this effort, the Chief Scientist of the Air Force awarded the Raven Team the 2001 Air Force Science and Engineering Award for Engineering Achievement.

Background The Raven program was the very first Air Force Space Battlelab initiative. This program offloaded tasking from larger, more sophisticated telescopes, such as the Ground-based Electro-Optical Deep-Space Surveillance and MSSS telescopes, for more challenging tasks. The program goal provided an autonomous system that required little or no operational support, thus providing significant cost savings.

The Space Surveillance Network is tied to the Integrated Threat Warning/Attack Assessment missile warning system at Cheyenne Mountain in Colorado Springs, Colorado. Requirements for certification are quite stringent including verification of the quality of the data (validated by the Space Warfare Center) as well as data communication protocols associated with sending data to the Space Surveillance Network.

Directed Energy Directorate's Computational Physics Team Recognized

Payoff Modern high performance computing (HPC) hardware and software enable researchers to study the emergent behavior of complex dynamical systems by solving the non-linear governing equations via direct numerical simulation. The Directed Energy Directorate's High Power Microwave Division's Computational Physics Team developed software to solve the equations of plasma physics while executing efficiently on modern parallel computers. The team applied this software to the design of high power microwave (HPM) systems.

Accomplishment The Air Force Office of Scientific Research (AFOSR) recognized the directorate's High Power Microwave Division's Computational Physics Team as an AFOSR Star Team. Dr. Robert E. Peterkin, Jr. (kneeling center left in photo) leads this six-member government team. Other team members include (left to right in photo) Dr. Keith L. Cartwright, Dr. Andy D. Greenwood, Dr. John W. Luginsland, Mr. Jeff T. MacGillivray, and Lt Joseph D. Blahovec, Jr.

AFOSR recognized the Computational Physics Team for their close collaboration between basic research efforts, computational skills, and experimentalist efforts. This collaboration enhances the division's ability to design efficient, compact HPM systems that meet the needs of the warfighter.

Background The primary goal of the Computational Physics Team is to develop advanced algorithms and visualization techniques for accurate, efficient, scalable simulation of the physics of plasmas. AFOSR and the Department of Defense (DoD) High Performance Computing Modernization Office (HPCMO) funded this team, and the HPCMO also provides HPC resources.

Because of the growing importance of HPM technology to the DoD, the team developed the Improved Concurrent Electromagnetic Particle-In-Cell (ICEPIC) and Multiblock Arbitrary Coordinate Hydromagnetics (MACH) plasma simulation codes. ICEPIC and MACH are portable general-purpose scientific computational codes that researchers apply to sparse and dense plasmas in complex geometries, primarily to help design and diagnose laboratory components for generating HPM.

By using ICEPIC to simulate the narrowband HPM source known as the Magnetically Insulated Line Oscillator (MILO), laboratory scientists understand aspects of radio frequency pulse shortening caused by bipolar flow across the anode-cathode gap. This understanding allows researchers to modify the MILO and produce an HPM pulse twice as long as achieved with previous designs.

Dr. Kenneth Boff Elected Fellow of the International Ergonomics Association

Payoff The selection of Dr. Kenneth R. Boff, Chief Scientist of the Human Effectiveness Directorate, as an International Ergonomics Association (IEA) Fellow enhances the directorate's reputation as a world leader in supporting the human factors design and acquisition of complex systems that are trainable, operable, maintainable, and safe. IEA is the worldwide association of ergonomics and human factors societies.

Accomplishment The Board of the IEA elected Dr. Boff a Fellow and conferred this honor at the IEA's annual meeting in San Diego, California. The IEA recognized Dr. Boff for international service to the profession and sustained superior contributions to ergonomics and human factors. This special honor recognized 23 individuals from among 16,000 members, representing 29 countries.

Background Ergonomics (or human factors) is the scientific discipline involving interactions among humans and other elements of a system to carry out a purposeful activity. Ergonomics improves human well being and overall system performance through optimizing human-system compatibility. The IEA promotes the knowledge and practice of ergonomics by initiating and supporting international activities and cooperation. The IEA serves the United Nations, the World Health Organization, the International Labour Organization, the International Social Science Council, and the International Standards Organization. Superior career accomplishments achieving international recognition form the basis for selection as an IEA Fellow.

Dr. Dee H. Andrews Receives the British Silver Medal

Payoff Mr. Trevor Truman, Royal Aeronautical Society President, presented the British Silver Medal to Dr. Dee H. Andrews (left) "in recognition of his considerable contribution to research in the field of warfighter training research and systems." Dr. Andrews received the award during the 89th Wilbur and Oliver Wright Lecture and Awards Ceremony at the society headquarters in London, England.

Accomplishment As division technical advisor for the Human Effectiveness Directorate's Warfighter Training Research Division, Dr. Andrews received the British Silver Medal for his contributions to the distributed mission training (DMT) research and development program. DMT uses various simulation, instructional, and networking technologies to create a synthetic battlefield, allowing warfighters to train as they intend to fight. DMT is not only revolutionizing training in the US Air Force, but also significantly impacting the training strategies of many allied air forces, especially in North Atlantic Treaty Organization countries and Australia.

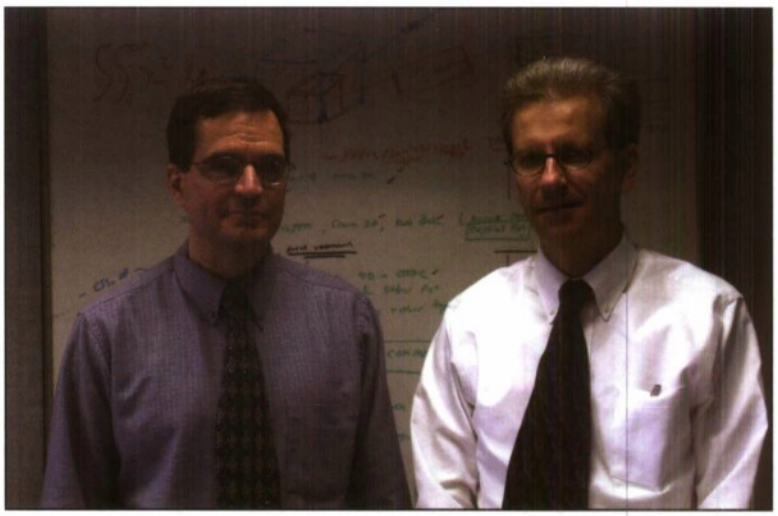
Background Dr. Andrews and the Warfighter Training Research Division conceived the idea of linking virtual (simulator), live assets, and constructive models to create a synthetic battlefield that allows warfighters to train on an on-demand basis. The directorate developed and improved many of the technical approaches necessary to make DMT possible. As warfighters become proficient at tactical mission tasks in highly realistic simulation environments (missions which are difficult to accomplish on training ranges such as four-ship aircraft vs. multi-ship aircraft engagements), pilots require less time practicing these skills when they actually utilize the training ranges.

Benefits of DMT include increased combat effectiveness by warfighters who will learn and practice mission critical skills more effectively and frequently, reduced training cost due to less use of operational equipment, longer life for weapon systems, and more accurate measurement of critical skill levels for mission teams.

Information Directorate Engineers Honored for Counter Drug Technology Efforts

Payoff Two Information Directorate engineers, assigned to the Information and Intelligence Exploitation Division, received the 2001 Department of Defense (DoD) Counter Drug Technology Development Program Technical Agent of the Year Award in recognition of their efforts to enhance the military's counter drug capability. The DoD Counter Drug Technology Development Program Office presented the awards to Mr. Walter V. Gadz (pictured on right) and Mr. Herbert J. (John) Mucks (pictured on left) at the annual Technical Agent Symposium in Arlington, Virginia.

Accomplishment The Technical Agent of the Year Award recognizes individuals who are effective, efficient, and proactive in executing technology programs that meet the needs of the counter drug community. The program office cited Mr. Gadz and Mr. Mucks for their teamwork throughout the development process, ensuring delivery of individual software technologies (information extraction, visualization, and timeline analysis tools) as a single, seamless tool and not just as individual capabilities. The directorate provided the software to Headquarters, US Southern Command in Miami, Florida; Headquarters, Joint Interagency Task Force, East Key West, Florida; and tactical analysis teams, making it one of the most widely used data analysis and display tools in the counter drug community.



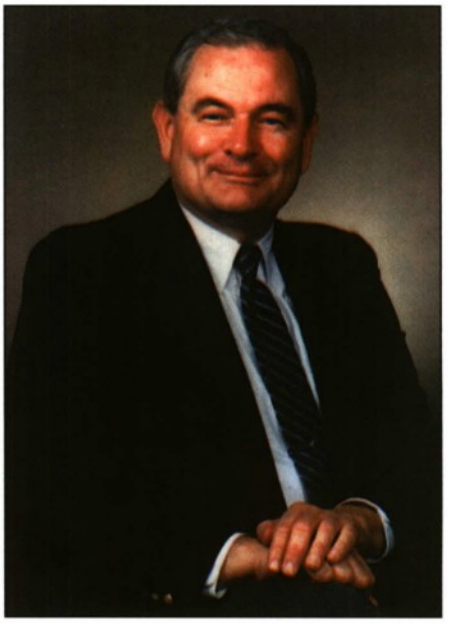
Background For years, the defense and intelligence communities primarily used timeline analysis to predict foreign government actions and response to world events. Software users can visualize events in time and geographically to reveal patterns that can be seen no other way. These patterns help analysts predict terrorist activity, narcotics activities, and other criminal behavior of suspects. They focus on investigations and limit wasted manhours. Timeline analysis also aids prosecutors in presenting clear, cohesive cases. The directorate provides this technology to civilian law enforcement agencies, which is consistent with the goals of the National Drug Control Strategy and the DoD mission.

Dr. Robert Spry Appointed Fellow of American Physical Society

Payoff The selection of Dr. Robert J. Spry as a "Fellow" of the American Physical Society (APS) recognizes individual achievement and enhances AFRL's reputation as a world leader in materials research and development. His contributions to science advanced the Materials and Manufacturing Directorate's in-house research efforts in areas directly benefiting the warfighter, strengthening national security, and greatly influencing the study of physics.

Accomplishment The APS recently named Dr. Spry a Fellow of their 40,000-member organization. Dr. Spry of the directorate's Nonmetallic Materials Division earned the appointment for outstanding lifetime achievement in physics including major contributions to the Air Force and the Department of Defense during more than 33 years of service to the nation. His efforts resulted in a number of critical advancements supporting operational and future systems vitally important to national security. The Forum on Industrial and Applied Physics of the APS recognized Dr. Spry for important contributions to semiconductor defect spectroscopy, analysis of nonlinear optical devices, and polymer conductivity and optical properties.

Background The APS, created over 100 years ago, is the cornerstone in the advancement and diffusion of knowledge of physics and the primary membership organization for physicists in the United States as well as a significant force in physics internationally. The APS Fellowship program recognizes members who made advances in knowledge through original research and publication, or made significant contributions in the application of physics to science and technology. The APS elects no more than one-half of one percent of the organization's membership to Fellow status in any given year.



Dr. Spry received his doctorate degree in solid state physics from the University of Illinois at Urbana-Champaign. He joined the directorate's Electromagnetic Materials Division in 1967, performing research in semiconductors, light-emitting diodes, laser windows, and infrared detectors. Later, he developed experimental devices and pioneered directorate studies that measure infrared luminescence, absorption, and spectral photo conductivity in semiconductor materials at low temperatures.

In 1981, Dr. Spry performed research in nonlinear optics and optical filters, and eventually carried the nonlinear research effort on to the directorate's Polymer Branch in addition to starting a new program in polymer conductivity. He mentors many students at Wright State University (WSU), where he serves as adjunct professor, and at the Air Force Institute of Technology. As a long-time science fair judge and advocate, he served on the West District (WSU) Science Fair Council since 1983. Dr. Spry is the author of 65 publications and patents and 90 scientific presentations.

Materials and Manufacturing Directorate Engineer Receives 2001 Commander's Cup Individual Award

Payoff Mr. George A. Slenski led several critical Air Force accident investigations and initiated a focused national attack on aging aircraft wiring issues. His efforts influenced major program decisions by the Air Force, National Aeronautics and Space Administration (NASA), the National Transportation and Safety Board, and Federal Aviation Administration (FAA), significantly improving the safety and reliability of multiple Air Force and commercial aircraft.

Accomplishment AFRL recognized Mr. Slenski, Materials and Manufacturing Directorate's Systems Support Division Electronics Failure Analysis team leader, with the Commander's Cup Individual Award. His selection further enhances the directorate's reputation as a national leader in electronics failure analysis and electrical wiring systems, and as the technical resource for critical accident investigations and problem resolutions. The AFRL Commander's Cup Individual Award, an annual corporate award, recognizes the person whose efforts contributed most significantly to the AFRL mission or image outside AFRL. Recipients' accomplishments have a substantial impact on AFRL and increase its credibility as a national research and development facility.

Background Mr. Slenski led a government and industry team that, in less than two weeks, identified the principal cause of a transport aircraft electrical mishap. The team also identified specific materials and design changes to prevent future failures. Mr. Slenski's efforts resulted in the replacement of control panels on the entire fleet of transport aircraft.

Due to several successful past interactions, NASA officials added Mr. Slenski to an independent assessment team to evaluate space shuttle maintenance practices. He led the wiring assessment team that identified several issues requiring immediate action prior to future flights. He communicated team findings to the head of manned space flights at NASA and to NASA center directors.

Mr. Slenski also organized and sponsored a conference on conductive residues found in aircraft fuel tanks. The meeting kicked off a $400,000 FAA research program characterizing fuel residues based largely on Mr. Slenski's findings. Guidance to FAA investigators resulted in a new theory for the formation of fuel tank residues and the influence on electrical failures.

Senior officials from the Department of Defense and the White House Office of Technology and Policy further recognized Mr. Slenski's expertise in aging wiring and electronic failure analysis methodology and requested him to participate on a team for defining national strategy in the area of aging wiring.

Mr. George Schmitt Receives Federal Laboratory Consortium Technology Transfer Award

Payoff The successful transfer of Air Force technology pays dividends to the consumer, industry, and the Air Force. Brake-by-Wire (BbW) and its related technologies could revolutionize the way manufacturers construct electrical systems in aircraft and braking systems in next-generation automobiles. Engineers expect BbW technology to offer increased safety and vehicle stability to consumers and provide benefits to automotive vehicle manufacturers, who will combine vehicle components into modular assemblies using cost-effective manufacturing processes.

Accomplishment The Federal Laboratory Consortium (FLC) for technology transfer recently awarded Mr. George Schmitt, a division chief with the Materials and Manufacturing Directorate, the Midwest Region Technology Transfer Award. Mr. Schmitt received the award for his work in BbW-related technologies.

Background In June 2001, AFRL and Delphi Automotive Systems signed a technical collaborative agreement to bring BbW technology to the automotive industry. While conventional brake systems found on cars today are hydraulic, BbW technology sends electrical signals to the brake system to stop a vehicle. The Air Force has an extensive background in landing gear and fly-by-wire systems, while Delphi will work to integrate BbW technologies into next-generation vehicle handling and safety systems.

Mr. Schmitt, Chief of the directorate's Integration and Operations Division, led several organizations assembling technical projects for this collaborative effort. Under his leadership, experts from three AFRL directorates (Materials and Manufacturing, Air Vehicles, and Propulsion) addressed electrical motors and actuators, high-temperature insulation materials, reconfigurable control technologies, fault-tolerant architectures, and reliable wiring and connectors.

Introducing the technology to the commercial arena also benefits the Air Force by creating a demand for shared components, thus reducing the component cost to government and industry for their respective applications. The collaboration will also leverage investments in more electric aircraft and provide needed large-scale technology validation.

Mr. Schmitt received first place in the Automotive and Aerospace category and honorable mentions in the Materials and Manufacturing and Consumer Products categories during the FLC's Midwest Region meeting at Argonne National Laboratory near Chicago, Illinois. His selection for the FLC Award recognizes outstanding individual accomplishment and enhances AFRL's reputation as a world leader in materials and manufacturing research and development.

Dr. John Maguire Receives 2001 Brimacombe Award for Research Excellence

Payoff The J. Keith Brimacombe Award recognizes outstanding researchers who work in the field of intelligent processing and materials manufacturing for at least 10 years and have made clear, recognized, and respected contributions to these areas. Dr. John F. Maguire's (pictured on right in both photos) research can solve several industry and scientific problems in nanomaterials processing research, determining the characteristics of metals and arranging grains properly in superconductors.

Accomplishment Dr. Maguire, a Materials and Manufacturing Directorate scientist, received the Brimacombe Award during the third Intelligent Processing and Manufacturing of Materials (IPMM) Conference in Vancouver, British Columbia, Canada. The IPMM cited Dr. Maguire, a research leader for the directorate's Manufacturing Technology Division, Materials Process Design Branch, for his contribution to soft and interfacial matter research, and development of material processing and new techniques in computer simulation and molecular dynamics.

Background Advanced future material applications, such as high-power radars, ultra-lightweight airframe structures, and large-adaptive space-based optics, require the development of new materials whose characteristics far exceed the capabilities of current materials. Discoveries in the area of soft, interfacial, and granular materials could provide new nano-matter with engineered properties and controlled structures.

Dr. Maguire performed research in electronic prototyping that applies new kinds of computation techniques to address contemporary problems in the simulation of matter. Specifically, he addressed the way crystals and grain structures pack together in space and time to determine the behavior and properties of materials.

An electronic prototyping computer application, developed by Dr. Maguire and his colleagues, allows the user to visualize how each of hundreds of thousands of grains position themselves according to the laws of physics. This computer application predicts the properties of this virtual material.

The application enables very rapid calculation of the forces between the particles and quickly determines where in space and when in time a pair of hard particles will collide. This is done hundreds of millions of times in the computer using algorithms based on artificial neural nets. In this approach, the computer learns the collision dynamics and trajectories of a relatively small number of "exemplars" and uses the particulate artificial neural net dynamics algorithm to rapidly interpolate for unknown trajectories.

Dr. Gail Brown Named Fellow of International Society for Optical Engineering

Payoff Dr. Gail J. Brown's selection for this coveted appointment recognizes her contributions over several years in the field of semiconductor research and development. She serves as the Materials and Manufacturing Directorate's principal scientist for research on innovative materials for infrared (IR) detector array applications.

Her leadership, ideas, and motivation led to the development of novel materials that enable the Air Force to maintain its technological advantage. Her accomplishments and selection as a Fellow of the International Society for Optical Engineering (SPIE) help advance the directorate's reputation as a leader in materials research and development, and recognize AFRL's efforts to support Air Force operational requirements.

Accomplishment Dr. Brown, a materials scientist and member of the directorate's Survivability & Sensor Materials Division, received an appointment as a SPIE Fellow. The International Society for Optical Engineering honored Dr. Brown for outstanding leadership in the development of semiconductor materials to improve IR sensors for current and future Air Force systems.

Background Several Air Force weapon systems incorporate imaging array systems that operate in the long and very long IR spectra in order to detect cold objects in darkness. However, while capability and performance demands on these systems are increasing, the space available aboard aircraft and spacecraft to house them remains the same or gets smaller. Hence, imaging array system components, especially IR sensors, must now offer improved performance to meet these demands.

Dr. Brown, a recognized expert in materials for IR detector array applications, specializes in the development of materials to improve the performance of IR sensors used on advanced imaging systems. Dr. Brown's research concentrates on the design, assessment, and demonstration of new semiconducting materials capable of outperforming today's industry standards—silicon and gallium arsenide.

Dr. Brown's pioneering research efforts led to the first reporting of many spectral features of semiconductor materials. In vital Air Force systems, sensors made with these materials offer greatly improved performance and high uniformity over large areas and wavelength tunability, while eliminating design complications and yield problems associated with earlier materials.

SPIE is an international technical society dedicated to promoting the engineering and scientific applications of optical, photonic, imaging, and optoelectronic technologies through various education and communications programs, meetings, and publications. SPIE is the largest international professional engineering society serving the practicing engineer and scientist in the field of optics and photonics. The society serves the global technical and business communities with more than 17,000 members worldwide in 75 countries.

Materials Research Sparks Award-Winning Development of New Aircraft Anti-Icing and Deicing Fluid

Payoff The fluid developed under the Anti-icing/ Deicing Fluid (ADF) replacement effort meets or exceeds the objectives established under the Air Force Small Business Innovation Research (SBIR) program. The new formulation is the first and only non-glycol ADF certified by independent laboratories and recognized by the Federal Aviation Administration.

Accomplishment Research sponsored by the Materials and Manufacturing Directorate led to the development of a new, less expensive aircraft anti-icing and deicing fluid that performs as well as or better than products currently in use. Developed by METSS Corporation of Columbus, Ohio, under an Air Force SBIR program, the new fluid is fully compliant with environmental regulations and is non-corrosive. It is so effective it earned the prestigious international Research and Development 100 Award from *R&D Magazine*.

Background Military and civilian airports use large quantities of glycol-based anti-icing and deicing fluids that are very effective. Unfortunately, these fluids are toxic and biodegrade too rapidly and also require special handling to avoid environmental problems. Under the direction of the directorate, METSS Corporation produced a commercially viable, environmentally friendly replacement for glycol-based fluids that eliminates the requirement for capturing or treating the fluid prior to its release into the environment.

The new ADF formulation is non-toxic and, thus, effectively addresses the major toxicity issues such as fluid disposal and water contamination. In fact, METSS uses 100% organic derivatives from agricultural products commonly used in food and cosmetic products to make ADF. Since these agricultural products are abundant, they are cost effective and easily renewable.

The METSS ADF imposes about half the short-term biochemical oxygen demand on the receiving stream when compared to propylene glycol-based materials. The new fluid is also infinitely soluble with water and non-corrosive to ferrous metals and non-ferrous alloys (no salts).

The improvements realized as a result of the new ADF help the Air Force comply with federal, state, and local environmental regulations, while reducing the total cost of anti-icing and deicing fluids. As demonstrated during the Air Force SBIR effort, the new technology is well suited for both military and commercial aircraft operations, which makes it technologically significant on a global scale.

Propulsion Directorate Researcher Wins Yates Tech Transfer Award

Payoff Ms. Sandra Fries-Carr, of the Propulsion Directorate's Electrical Technology and Plasma Physics Branch, won the prestigious General Ronald W. Yates Award for Excellence in Technology Transfer. Transfer of the Directorate's fluorene polyester (FPE) high-performance capacitor dielectric material fills a critical need for advanced, high-performance capacitors for military applications, while providing a low-cost solution for multiple applications in commercial products.

Accomplishment The Air Force Materiel Command recognized Ms. Fries-Carr for her work in leading the development, transition, and transfer of the FPE capacitor dielectric material. These films will dramatically increase the performance, reliability, and applicability of the capacitors upon which modern commercial and military electric systems rely.

Ms. Fries-Carr responded to the need for a better performing capacitor material by initiating a program with industry to develop and produce a capacitor film to meet high-performance military requirements. This effort involved over 17 organizations—2 government and 15 commercial enterprises.

Background While the military requires high-performance capacitors to satisfy mission requirements, the military is a low-volume user compared to commercial applications. Capacitor and capacitor film manufacturers are reluctant to develop capacitors or film to meet these requirements as long as their current capacitors satisfy high volume commercial customer applications. Also, the manufacturer was ready to discontinue a popular, high-performance film, leaving several military applications without a suitable replacement.

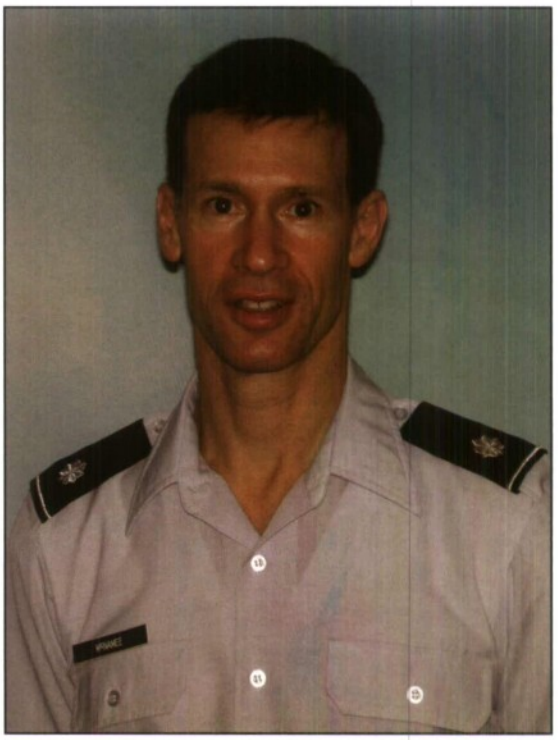
The directorate worked with film producers, as well as capacitor manufacturers, for several years to produce a capacitor-grade, 12-micron film. This film has a high-temperature capability of 250°C (two times the current state-of-the-art) and twice the breakdown strength of current, high-performance films.

A need also exists for thinner films in the 2- to 6-micron range for certain applications. The directorate is currently testing this film. Their efforts resulted in one firm producing the casting process for these thinner films and two other firms using the casting process in a production mode.

Lt Col McNamee Receives Science and Engineering Award for Research Management

Payoff Lt Col Joseph McNamee, PhD, of the Propulsion Directorate, received the Air Force Science and Technology Award for Research Management. The Air Force recognized Lt Col McNamee for his leadership, technical skills, and unparalleled ability to inspire others with a passion for his vision. His work as a team builder and advocate for aerospace power research and development has a tremendous impact on power research throughout the Department of Defense (DoD).

Accomplishment Lt Col McNamee created a disciplined approach in his management of over 150 research programs in the directorate's Power Division. While serving as the division's deputy director, he developed key partnerships with Air Force users, product centers, DoD, and national laboratories to define future aircraft, space, and directed energy weapon system power requirements.



Background The directorate's Power Division conducts a wide array of research and technology development that includes basic research in plasma physics; aircraft electrical components of all types; lightweight, high-power generators and their components; spacecraft power systems and thermal management; nanotechnology projects for advanced power systems; superconductivity; advanced energy storage; and a host of others. This wide spectrum of research provides critical enabling technologies for systems fielded by all DoD components and will open up unimaginable capabilities for future systems.

Lt Col McNamee reinvigorated the Inter Agency Power Group (IAPG), exchanging key research results and creating productive collaboration among the services. Working groups of the IAPG that had not met for two years are now actively meeting and contributing to the needs of the entire DoD. In addition, his efforts led to a proposed $50 million Dual Use Science and Technology program to accelerate key power system technologies.

Dr. Russell L. Spyker Receives the Air Force Science and Engineering Award for Engineering Achievement

Payoff The Air Force awarded Dr. Russell L. Spyker of the Propulsion Directorate the Air Force Science and Engineering Award for Engineering Achievement. Dr. Spyker is the leader of a nationally renowned power electronics research and development team that generated astonishing results and productivity during 2001.

Accomplishment An exceptionally resourceful engineer, Dr. Spyker, led his team in conducting 10 multi-disciplinary research projects to develop original and inventive solutions to a number of aerospace electrical power system problems. Collaborating with industry partners, Dr. Spyker's accomplishments include the development of low-cost capacitor packaging, current transformers, solid-state circuit breaker research for the National Aeronautics and Space Administration's (NASA's) electric airborne power unit (APU) for the Space Shuttle, and ultra capacitor applications for battery-like performance with 100 times the life-cycle improvement over batteries.

Background Capacitors for military application typically require costly, hermetically sealed units. The non-hermetic capacitor packaging developed under Dr. Spyker's leadership is one-sixth the cost of sealed capacitors and saves 30% weight and volume, while meeting or exceeding military and commercial specifications. His ratio-metric current transformer overcomes stray inductance, allows fine tuning after installation, reduces manufacturing costs, and provides a 70% weight and volume savings over the state-of-the-art.

The Air Force selected Dr. Spyker to serve on NASA's Independent Assessment Team for the electric APU, the highest priority upgrade program for the Space Shuttle. He identified several technology shortcomings including the lack of adequate short-circuit fuse protection.

The fault current from the proposed 270-volt direct current batteries could reach 4,000 amps, and no existing space-qualified circuit breaker could interrupt this magnitude of current. To solve this problem, Dr. Spyker experimented with an innovative design that incorporates solid-state switches in parallel with a circuit breaker. Dr. Spyker and his team completed the design, fabrication, and successful demonstration of his novel solid-state circuit breaker in six weeks, just in time to meet NASA's critical decision milestone on the electric APU program.

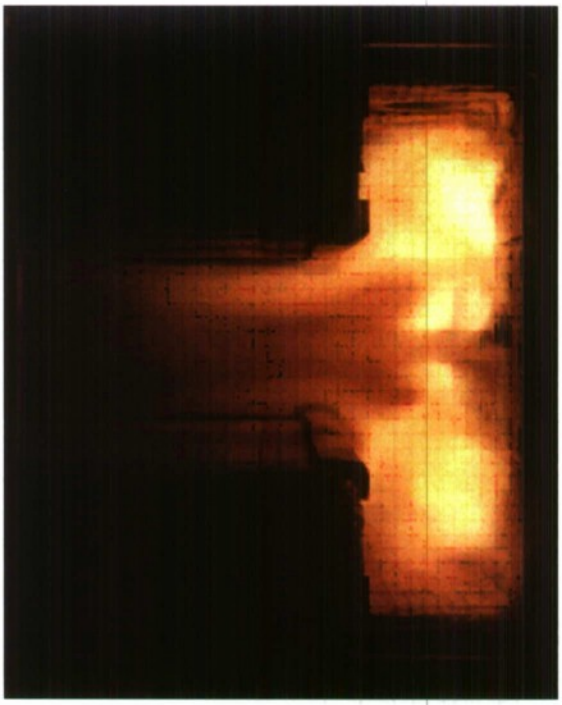
Searching for a replacement for low discharge-rate batteries that power thousands of military and commercial aerospace subsystems, Dr. Spyker and his team exploited the unique characteristics of ultra-capacitors, a new high energy density storage device. Using these capacitors at a slow discharge rate gives battery-like performance and offers nearly a hundredfold life-cycle improvement over existing batteries.

Propulsion Directorate-Led Combustion Research Named Pollution Prevention Project for 2001

Payoff The Strategic Environmental Research and Development Program (SERDP) Office, a joint Department of Defense, Department of Energy (DOE), and Environmental Protection Agency program, named the Propulsion Directorate-led trapped vortex combustion project the Pollution Prevention Project of the Year for 2001. The Trapped Vortex program is a joint effort with the Navy, General Electric Aircraft Engines (GEAE), Innovative Scientific Solutions Inc., and the DOE.

The Trapped Vortex program began as a potential method to keep aircraft jet engines lit even when operating at the extremes of the flight envelope. The trapped vortex combustor (TVC) satisfies the initial requirement and reduces pollution while increasing performance.

Accomplishment The TVC project produced impressive results for jet engine operation while enabling significant reductions in emissions. Use of a TVC in a jet engine improves performance by allowing a 40% expansion of the operating envelope, a 50% decrease in engine blowout occurrence, and a 50% improvement in relight if blowout occurs.



The pollution prevention numbers are equally impressive. Using TVCs in turbine engines could reduce aircraft emissions to 50% below the International Civil Aviation Organization standard for nitrogen oxides (NOx) as well as a comparable amount for volatile organic compounds (VOCs).

Compared to conventional combustors used in marine gas turbine engines, a trapped vortex combustor-equipped turbine engine will reduce yearly emissions of NOx and VOCs from Navy ships by 52% and 60% respectively. When applied to various fleets of aircraft, turbine powered ships, and stationary power plant turbines, TVC use will reduce NOx emissions by 95 million pounds per year and VOCs by 300 million pounds per year.

Background The TVC concept grew from fundamental studies of flame stabilization conducted by the directorate. The TVC is an innovative design that departs from the traditional swirl stabilized designs used in turbine engines for the past 40 years. It consists of a pilot combustor for stability and a main combustor for power.

The pilot section includes cavities that capture or trap a flame vortex, thus the name TVC. It is a simple design that provides low NOx because of a good mix in the main and trapped vortex pilot combustors. The directorate, GEAE, Naval Sea and Air Systems Commands, and National Energy Technology Laboratory are developing the TVC with funding from SERDP and other sources.

Dr. Nelson Forster Receives Air Force Science and Engineering Award for Manufacturing Technology

Payoff The Air Force recently awarded Dr. Nelson Forster, a Propulsion Directorate scientist, the Air Force Science and Engineering Award for Manufacturing Technology. Dr. Forster's team developed a process to manufacture bearing cages from carbon-carbon materials for use in advanced turbine engines, air vehicles, and missiles.

These bearing cages enable turbine engine operation far beyond current operational capabilities. Manufacturers can use this innovative process to make components for demonstrator engines for the Integrated High Performance Turbine Engine Technology (IHPTET) program, engines for unmanned air vehicles, and high-speed missile cruise missile engines.

Accomplishment Dr. Forster applied his internationally recognized expertise in mechanical systems design to invent a process to develop high-temperature bearing cages. This innovative process uses a carbon matrix tube reinforced with carbon fiber in a fabric woven in a multi-directional arrangement. After processing, the resulting material provides low density, high-thermal conductivity, low friction, and exhibits essentially no wear.

Bearings with this cage material generate substantially less heat and demonstrate a much lower operating temperature than bearings with traditional metal or polymer cages. This material is available at low cost—only 10% of the total bearing cost.

Background The IHPTET program is a national program coordinating the efforts of the Air Force, Army, Navy, the National Aeronautics and Space Administration, and the major US turbine engine manufacturers. The overall goal of this effort is to double the propulsion capability of turbine engines relative to the baseline technologies in operation in 1987.

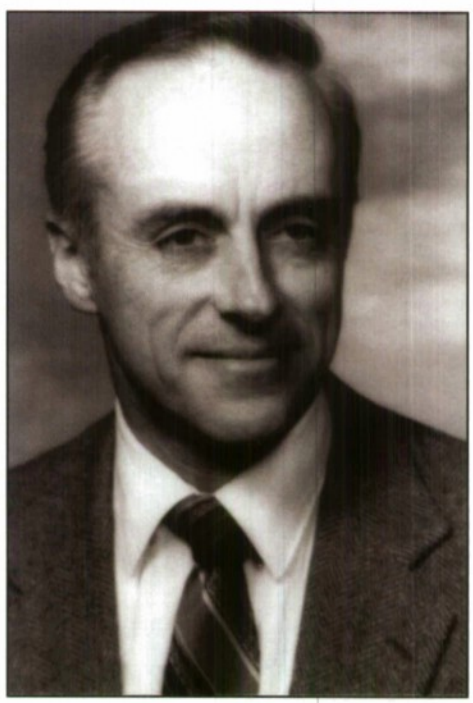
Existing turbine engine bearing cages use either metal or polymer-based materials. Such bearings will seize due to thermal run-a-way at temperatures higher than 550°C—the temperatures required for Mach 3 turbine engines. Other polymeric materials, such as phenolic cages, will melt, char, or burn during these required conditions.

To date, carbon-carbon is the only material to withstand these conditions and provide the required bearing performance. Testing of these bearing cages also indicates they offer ten times the improvement in bearing life for fuel-cooled bearings and show promise in applications to high-speed control moment gyros for military satellites. Directorate engineers plan to test carbon-carbon bearing cages in the XTL-16 and XTC-67 IHPTET demonstrator engines in 2004.

Dr. Mailloux Awarded IEEE Millennium Medal

Payoff The Antenna and Propagation Society of the Institute of Electrical and Electronic Engineers (IEEE) presented Dr. Robert Mailloux with the Millennium Medal in recognition of his technical accomplishments and service to the field of antenna technology. A select and special group of IEEE members receive this honor for outstanding contributions to a section or society.

Accomplishment Dr. Mailloux of the Sensors directorate's Electromagnetics Division, received the IEEE Millennium Medal in recognition of his technical accomplishments and service in the field of antennas and propagation.



Background Dr. Mailloux, the senior scientist for antenna technology, is the recipient of many awards for his technical papers and inventions. He is a Fellow of the IEEE, an AFRL Fellow, and winner of the IEEE's 1991 Harry Diamond Memorial Award. His technical papers won two IEEE awards, in addition to the Air Force Marcus O'Day and Fred Diamond "best paper" awards. He authored a number of textbook chapters in antenna technology and also wrote the "Phased Array Antenna Handbook." Dr. Mailloux served a number of offices within the IEEE, including president of the IEEE's Antenna and Propagation Society. The IEEE is the world's largest technical professional society with more than 320,000 members.

Engineer Receives Association of Old Crows Award

Payoff Mr. Neeraj Pujara of the Sensors Directorate, Reconnaissance, Strike and Combat Identification Branch, received the Association of Old Crows (AOC) 2000 Navigation Warfare Award for his role in championing three high priority programs. His significant developments in advanced technology programs include the areas of information superiority, electronic warfare, and navigational warfare.

Accomplishment Mr. Pujara received the AOC's 2000 Navigation Warfare Award for work accomplished in the Integrated Global Positioning System (GPS) Electronic Combat (INGECT) program, the Advanced Tactical Targeting Technology (AT3) program, and the Theater Missile Defense Eagle Smart Sensor and Automatic Target Recognition (TESSA) IV program.

Background Mr. Pujara's accomplishments include overseeing three multi-million dollar programs, which directly support the warfighter. The INGECT flight test program used two aircraft sharing precise GPS position, velocity, and time information. This system will allow the warfighter to locate ground-based electronic threat emitters much more accurately by enabling the High-Speed Anti-Radiation Missile Targeting System. INGECT exceeded all operational performance expectations and goals while simultaneously maintaining cost and schedule.

The AT3 uses multiple aircraft, each equipped with sophisticated electronic equipment, to locate and destroy mobile air defense units. This key-enabling technology will enhance GPS for precise position, velocity, frequency measurements, and atomic clocks for precision time and for periods of GPS outage. It will compute a precise threat ground emitter geolocation to an unprecedented 50 meters, at ranges beyond 50 nautical miles in less than 10 seconds.

TESSA IV, a joint AFRL and Theater Missile Defense System Program Office program, provides the F-15E aircraft with an enhanced multisensor fusion advanced target recognition capability that enables the navigation reference information required to fuse and align onboard sensors. Aircraft will soon engage time-critical targets by fusing the outputs of the aircraft radar and forward-looking infrared for never-before attainable, longer-range, higher-confidence target recognition.